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Journal
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SOME CHARACTERISTICS OF AMERICAN COALS IN BY-PRODUCT COKING PRACTICE.*

BY

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BEFORE taking up the more technical phase of the subject it may not be amiss to discuss some of the broader relations of the American by-product coke industry.

The bulk of our material civilization during the past century has been built up by iron and energized by coal. These two are linked by coke. Next to the substitution of the shaft furnace for the old forge or bloomary, the greatest improvement in the iron industry was the substitution of coke for charcoal. It is difficult to realize that this important step was taken, with many misgivings, less than two centuries ago in England and less than seventy years ago in America. It was between 1730 and 1735 that Abraham Darby [1]—after six sleepless nights, it is related—succeeded in making the first cast of iron from a coke-fed furnace in England. Other sporadic efforts had undoubtedly been made previous to that time, but it was then that a continuous development of the coke industry in England may be said to have started. On the continent of Europe the regular use of coke was not introduced until a number of years later, while in

* Presented at the stated meeting of the Institute held Wednesday, March 20, 1918.

[1] Percy's Metallurgy (1864), p. 886.

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America it was not until 1850[2] that it began to exert an appreciable influence upon the manufacture of pig iron. In 1849 there was not a single coke furnace in blast in this country. Immediately after the Civil War, however, the demand for coke underwent a phenomenal development, at a rate which shows no signs of slackening. The coke industry is now truly regarded as an integral and vital part of the iron and steel industry. Not more than 110,000 tons[3] of coke were consumed in the production of pig iron in 1865. Twenty-five years later, in 1890, the annual consumption was about 10,000,000 tons. Fifty years later, in 1915, 36,700,000 tons of furnace coke and 1,700,000 tons of foundry coke were consumed. Last year (1917) the consumption of furnace and foundry coke was probably in excess of 50,000,000 tons. Thus in the past two years alone the industry has increased even more than in the phenomenal twenty-five-year period preceding 1890.

Up to about 1893 the country was dependent upon beehive coke alone. Now please note that so soon after the establishment of the industry, when it had already attained an enormous growth and had so revolutionized the iron industry that coke instead of charcoal was recognized as the standard fuel for the blast furnace, even at this time men could foresee within a comparatively short period the same extinction that had virtually befallen the charcoal industry. Only a narrow range of coals can be used to make good metallurgical coke in the beehive oven. The supply of such coals was rapidly approaching exhaustion. In Belgium and Germany the exhaustion of beehive coals had begun to force the introduction of the by-product oven, irrespective of any other economic considerations.

In a paper read a year ago, before The Franklin Institute, by Mr. C. J. Ramsburg,[4] there were brought forward three facts that are of great importance in this connection:

> 1. For every ton of coke made in the by-product oven there is saved in fuel value alone the equivalent of 825 pounds of coal.

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[2] "Iron in All Ages," Swank, p. 370.

[3] Figures throughout this paper are in net tons, except where otherwise indicated.

[4] JOURNAL FRANKLIN INSTITUTE, vol. 183, 1917, p. 391.

2. For every ton of coke made in the by-product oven and applied to blast-furnace purposes there is a direct saving of 482 pounds of coal (200 pounds wasted in beehive oven + 282 pounds saved in blast furnace, due to the superiority of by-product coke).

3. The by-product oven, by reason of its great flexibility of control, enables us to make good metallurgical coke from a very wide range of coals.

The development of the by-product coke oven is as vital to the modern iron and steel industry as was the substitution of coke for charcoal. For all practical purposes it has indefinitely prolonged the life of this great business, because the new reserves of coking coal that it has opened up and that are actually in sight are far more than sufficient to take care of the estimated iron ore resources of the world.

The phase of any industry that vitally interests us nowadays is its relation to winning the war. Industrially and scientifically, only those subjects that have a bearing on this great problem should occupy our attention at this time. Let us consider this aspect of the by-product coke industry. The vital connection of its main product—coke—with the iron and steel industry would alone suffice to place it in the front rank of the "essentials"; but, more than this, its by-products are recognized as being indispensable to the conduct of modern warfare. One need only mention ammonia, the indispensable source of ammonium nitrate and the potential source of nitric acid; benzene; phenol; picric acid; naphthalene with its mono-nitro derivative; cresol for antiseptic surgery; and, finally, toluene and trinitrotoluene, which is veritably the super-necessity of up-to-date artillery. Besides these, there are a host of coal-tar derivatives, employed for military and surgical purposes, which it would be very difficult to do without. The by-product coke oven is by far the largest source of these materials. Its relation to our toluene supply is of particular concern. Trinitrotoluene (T.N.T.), which can only be produced from toluene, is the only known high explosive that combines the merits of safety, reliability, and extraordinary power with the requisite capability of large-scale production. Notwithstanding the fact that we have one or two other large sources of toluene, it is unquestionably true that the by-product coke oven is by far the most important producer. Moreover, it is the one and only source that

can be absolutely depended upon to make toluene of the highest purity—especially in respect to freedom from paraffins.

All the facts, when carefully studied, justify the assertion that the by-product coke industry is one of the most vital to the winning of the war. So essential is this industry to the conduct of modern warfare that the striking power of each nation may, to a great extent, be measured by its supply of the by-products of coke. The extent of German preparation and advantage in this respect warrants our earnest consideration.

It is difficult to obtain trustworthy statistics as to the actual amount of by-product coke made in the various countries of the world. Fortunately, however, we have very reliable figures [5] for ammonium sulphate. Such figures as have been tabulated for the production of this material from coke ovens may be taken as an index to the extent of by-product recovery practised in each country.

In 1907 Germany produced 282,700 tons of ammonium sulphate from by-product coke ovens. This was more than the production from the same source *in all other countries combined*. In the same year the United States produced 68,970 tons of ammonium sulphate from by-product coke ovens. In 1913 the German industry produced 523,114 tons, which exceeded by over 100,000 tons the combined production of the coke ovens of the United States, England, France, Belgium, and Holland. The seizure of Belgium and northern France probably gave the Central Powers an advantage in coke-oven resources equivalent to an annual production of 100,000 tons of ammonium sulphate more than the combined production of the Entente Allies plus all the neutral countries of the world. Roughly, this advantage is equivalent to the product of coking 10,000,000 tons of coal. The military significance of these figures is not difficult to realize.

The fact that in the short space of three years great steps have been taken towards equalizing this advantage is an everlasting credit to American enterprise. The year 1917 showed a gain of more than 10,000,000 tons of by-product coke over the year 1914, which is probably equivalent to an increase of 14,000,000 tons of coal used in by-product ovens. Ovens now under con-

[5] Annual reports on sulphate of ammonia prepared by the American Coal Products Company. The original figures in the report for 1914 are given in metric tons, which are here transposed to net tons.

struction have an additional capacity of over 10,000,000 tons of coal per annum.

Even under the most favorable conditions, however, the American production of by-product coke in 1918 will be less than the German production at the beginning of the war. The total German production for 1912 was about 32,000,000 and for 1913 about 35,000,000 tons, while the United States produced 22,000,000 tons in 1917 and will probably produce 27,000,000 tons in 1918. When it is recalled that we are still making beehive coke at the rate of 33,000,000 tons per year—nearly as much as the entire German production in 1913—it will be seen that there is still much work to be done.

In fact, it must be admitted that the by-product oven has so far accomplished little more than taking care of the natural increase of coke production in America. It is a mistake to suppose that we have really done much toward abolishing the beehive oven. The amount of beehive coke made per year has undergone no appreciable diminution since 1906.

These 33,000,000 tons of beehive coke represent the loss of the following products:

TABLE I.

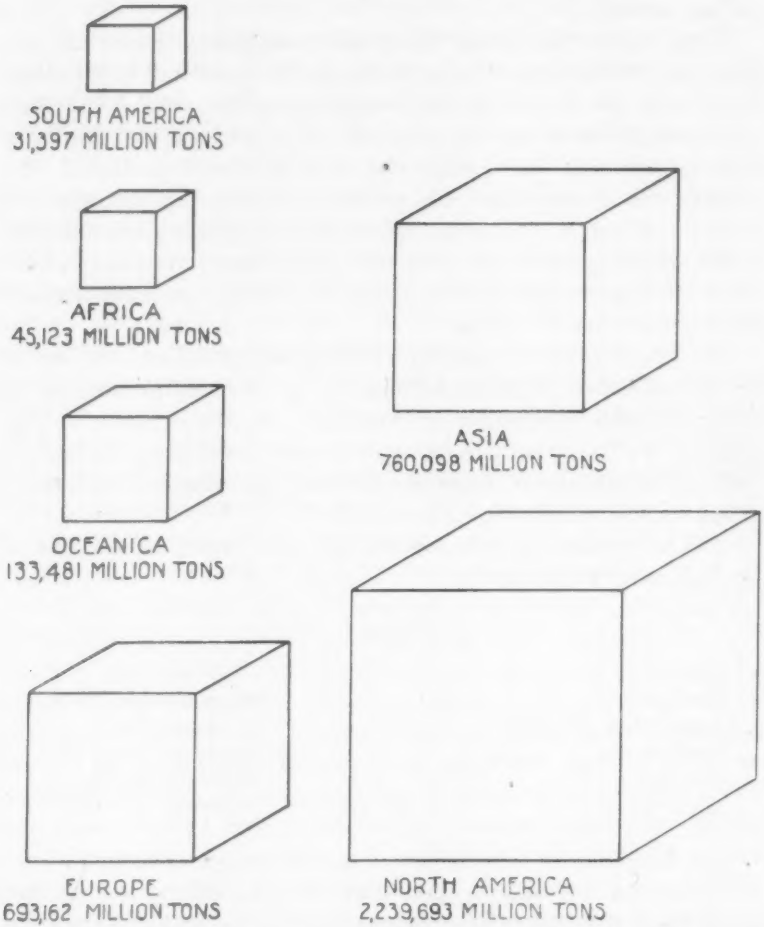
Coke	2,475,000 tons.
Tar	396,000,000 gallons.
Ammonium sulphate	545,000 tons.
Surplus gas	300,000,000,000 cubic feet.
Benzene	82,500,000 gallons.
Toluene	20,000,000 gallons.

Let us consider very briefly what these figures mean.

Two and one-half million tons of coke per year, which is based upon the loss in the beehive oven alone and does not take into account the large saving due to superiority of by-product coke in metallurgical practice, would keep fifteen 450-ton blast furnaces in continuous operation, or would supply the entire foundry business of the United States and leave over three-quarters of a million tons available for domestic purposes.

Four hundred million gallons of tar would, if used for fuel purposes alone, be equivalent to 2,200,000 tons of coal. It would supply enough fuel to produce 10,000,000 tons of open-hearth steel—which would fill the total estimated yearly requirements of

FIG. 1.



BITUMINOUS COAL RESERVES OF THE WORLD CONTINENTS IN MILLION TONS METRIC.
Production—1910.

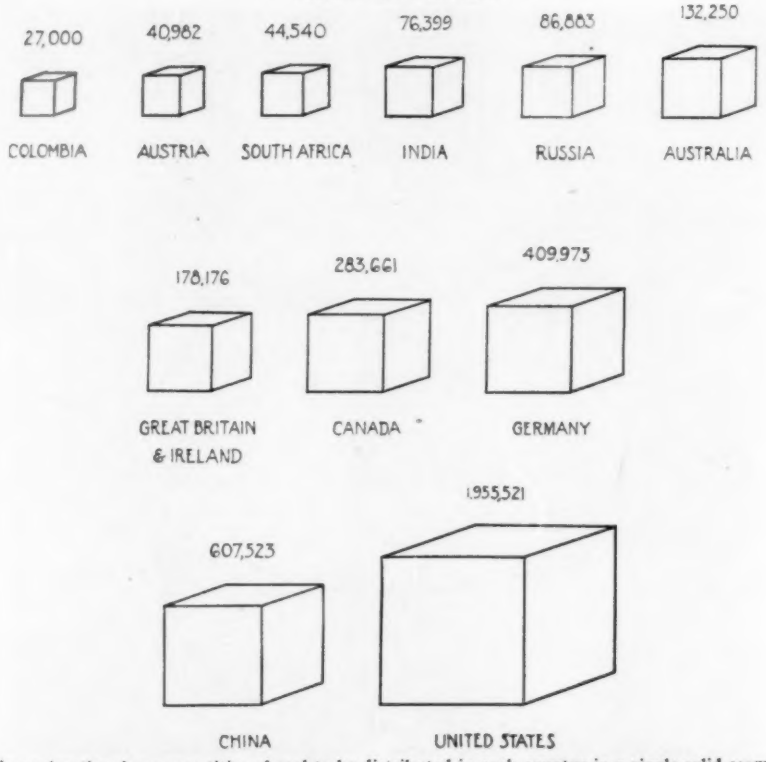
	Million tons		*Million tons*
Australia	10.0	Great Britain	264.5
New Zealand	2.23	Spain	3.55
China	14.59	France	38.57
India	12.09	Belgium	23.13
Japan	14.79	Germany	221.98
South Africa	5.5	Austria-Hungary	38.0
Canada	13.01	Italy	0.40
United States	445.81	Sweden	0.21
Mexico	2.45	Russia	24.57

Other countries . . 8.0 million tons

the United States and its Allies for steel for military purposes.[6]

Five hundred and forty-five thousand tons of ammonium sulphate are nearly equivalent to the entire annual production of the German Empire just prior to the war. This annual waste of valuable ammonia would furnish about 438,000 tons of nitric

FIG. 2.
MILLION TONS METRIC.



Assuming the above quantities of coal to be distributed in each country in a single solid seam 6 feet thick, the respective coal-bearing area would compare as shown in figure 2 A:

acid. A discussion of what this means from a military standpoint is not my purpose, but it would be of interest, in passing, to note that the estimate made previous to the war, by military authorities, for the annual nitric acid requirements of this country in case of war was 180,000 tons.

[6] *Iron Age*, January 3, 1918, p. 57—estimate for 1918.

From the standpoint of food supply this is even a more serious proposition. The permanent loss every year of more than half a million tons of ammonium sulphate—one of the most important nitrogenous fertilizers—might well arouse solicitude at a time when every effort is being made to increase our crop production. By ordinary agricultural practice about 100 pounds of ammonium

FIG. 2A.

COMPARATIVE RESERVES OF BITUMINOUS COAL.

sulphate are used per acre of cultivated land. We are therefore *burning up* every year in the beehive ovens enough nitrogen to fertilize 11,000,000 acres. It has been thoroughly demonstrated that the application of 100 pounds of ammonium sulphate to an acre of average wheat land (producing normally, say, 20 bushels) will increase the yield by about 8 bushels. Our wasted fertilizer

would therefore be capable of increasing our wheat production by 87,000,000 bushels a year without additional labor.

Three hundred billion cubic feet of gas are nearly equivalent to the amount of natural gas consumed for industrial purposes in the states of Pennsylvania, Ohio, and West Virginia, which are

FIG. 3.

Coke made from Pittsburgh seam coal (Allegheny County, Pa.), mixed with 20 per cent. Elkhorn seam coal (Kentucky).

the three largest consumers of natural gas in the Union. The diminution of the natural gas supply is a matter of grave concern in many important industrial centres, and by-product coke oven gas is undoubtedly one of the most promising sources of relief. The same piping and appliances now used for natural gas can with insignificant changes be used for coke-oven gas, and the

great benefit that would result from obviating the radical and expensive alterations of equipment otherwise necessary hardly needs to be pointed out. A value of 8 cents per thousand cubic feet for the coke-oven gas is a conservative figure from a natural gas standpoint, and would make the loss amount to $24,000,000 a year for this product alone.

FIG. 4.

Block of typical coke from coals of Pittsburgh district. (Slightly less than half-size.)

Eighty-two million gallons of benzene would be of great value in replacing or supplementing gasoline as a special motor fuel for military purposes, to say nothing of its application to making picric acid, an important high explosive. One hundred gallons of benzene are equivalent, in efficiency, to 115 gallons of gasoline; for any sort of military vehicle of limited fuel-carrying capacity this is an important fact. Eighty-two million gallons of benzene

would, if used for such purposes, effect a saving of about 12,000,000 gallons of gasoline.

Twenty million gallons of toluene would furnish enough T.N.T. to make 100,000,000 3-inch shells—quite a formidable argument.

Military values are what count nowadays, and one cannot estimate military values in terms of dollars and cents. Yet, for sake of completeness, we may sum up this situation in terms of very conservative *money* values under normal conditions.

FIG. 5.

Coke from 100 per cent. Illinois coal (District 6, Bed 6). (Note pebbly seam.)

TABLE II.

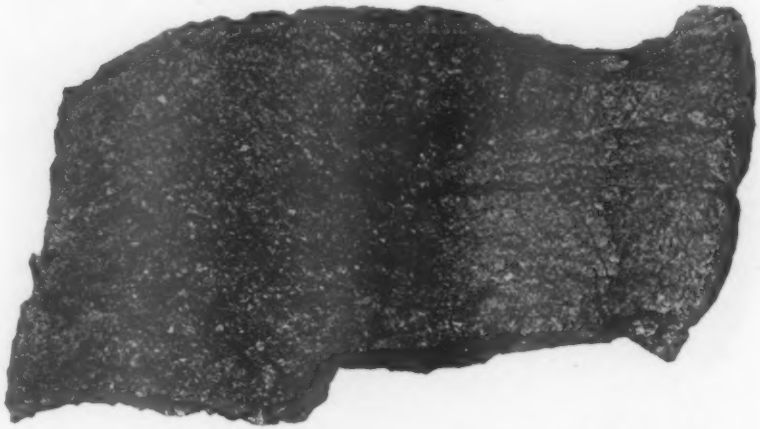
2,475,000	tons coke at $3.80	$9,405,000
396,000,000	gallons tar at 3½ cents	13,860,000
545,000	tons ammonium sulphate at $60	32,700,000
300,000,000	M. cubic feet gas at 8 cents	24,000,000
102,500,000	gallons motor fuel[r] at 15 cents	15,375,000
		$95,340,000

It is important to realize that this annual sum total of nearly $100,000,000 worth of the country's natural resources is not merely going unutilized every year, but is absolutely destroyed—

[r] Including only benzene and toluene. If all the available light oil constituents were included we would have at least 120,000,000 gallons motor fuel.

gone without the slightest possibility of recovery. It exceeds the value at the ovens of all the *coke* made in the United States in *1914*. In comparison with this gigantic waste, the cost of replacing the antiquated beehive with modern by-product recovery apparatus sinks into insignificance; even at present prices the replacement could be accomplished for less than $300,000,000. The war is costing the United States about $30,000,000 per day. This rate of expenditure would pay for the abolition of every American beehive oven in ten days.

FIG. 6.



Coke from 100 per cent. Illinois coal (District 7, Bed 6).

Perhaps we are departing too far from the scope of what was intended to be a technical paper, but this phase of the subject is one that vitally concerns all of us at the present moment, and every possible agency should be interested and engaged in accelerating the change of the industry to the modern basis. The principal—and probably the only important deterring—factors are the present high cost of material and labor and the difficulty, under present conditions, of financing the expensive plants required. There is a rather strong temptation—which must be thoroughly understood and guarded against—to resort to cheaper forms of construction that have been tried and found wanting in the past, and which, if yielded to, will only discourage and delay the complete establishment of the industry. It would seem that the government might well assist in furnishing or reinforcing the capital

necessary for a wholesale and immediate eradication of the beehive oven. The immediate practical, military benefits would be a sufficient argument, aside from the permanent conservation and the assured stability of the industry. Any development that can increase our wheat crop by nearly 90,000,000 bushels per year, that can more than double our material for high explosives, that is absolutely necessary in order to ensure to America and its Allies an unquestioned superiority in modern munitions, should be encouraged and hastened with every possible facility.

FIG. 7.

Coke made from unmixed coal, Pittsburgh seam, Lower Connellsville district, Fayette County, Pa.

Nor must it be forgotten that the beehive oven is not the only spendthrift of the important by-products of coal. The householder who burns a hundred tons of Pittsburgh coal in the winter months is likely, while standing aghast at the "Crime of the Beehive Oven," to forget that he himself is accessory in what is in the aggregate a greater crime. Table III, compiled from the statistics of the United States Geological Survey for the year 1915, shows the distribution of the coal produced in the United States.

Every encouragement should be given to the use of coke, gas, and briquetted fuel, which not only are important in national conservation, but are intrinsically cleaner, more economical, and more convenient.

TABLE III.

Consumption of Coal and Lignite in the United States in 1915.
(M. R. Campbell, U. S. Geological Survey, Professional Paper 100-A.)

	Net tons.	Per cent. of total.
Railroad fuel	122,000,000	28
Steamship fuel	10,700,000	2.3
Beehive coke	42,300,000	9.3
By-product coke	19,500,000	4.3
Coal gas	4,600,000	1.0
Domestic and small steam trade	71,300,000	16.0
Industrial steam trade	143,800,000	33.0
Exported	18,800,000	4.0
Used at mines	9,800,000	2.0
Special uses	700,000	0.1
Total	443,500,000	100.0

FIG. 8.

Coke from unmixed coal, Pittsburgh seam, Westmoreland County, Pa. Made in wide oven. Somewhat overcoked.

All such considerations, vital as they may seem to the needs of the present moment, are in a larger sense dwarfed by the significance of America's enormous preponderance in reserves of coking coals. These are such as to ensure the stability and normal growth of the industry for many centuries in a sense that is true for no other country. The statistics graphically presented in Figs. 1 and 2 have been drawn up from the elaborate report of the Twelfth International Geological Congress on the Coal Resources of the World. Of course, the limitations of all such figures may readily be recognized, but they serve very well as a practical working basis on which to estimate important economic relations.

The figures for bituminous coal may be taken as a *comparative* index of the reserves available for making coke. It is the by-product oven that makes this broad generalization possible. Consider, with these statistics, the supplementary figures in Table IV for the principal iron reserves of the world, compiled by Edwin C. Eckel.[8] It needs no prophetic imagination to foresee that the future of the vast industries that are based on these two materials must largely rest with America, and her duty to conserve such resources becomes more than a local necessity; it is an international obligation.

TABLE IV.

Principal Iron Ore Reserves of the World.

District.	Minimum.	Maximum.
Lake Superior Region	2,000,000,000	2,500,000,000
Southern red ores	1,500,000,000	2,000,000,000
Texas brown ores	600,000,000	1,000,000,000
Other Southern ores	500,000,000	750,000,000
Northeastern States	300,000,000	600,000,000
Western States	300,000,000	700,000,000
Total United States	5,200,000,000	7,550,000,000

Continent.	Annual ore tonnage.	Equivalent tons metallic ore.
North America	14,710,000,000	6,455,000,000
South America	8,000,000,000	5,000,000,000
Europe	12,032,000,000	4,733,000,000
Total	34,742,000,000	16,188,000,000

It may be of interest to survey the present distribution of the by-product coke industry in America, and the way in which the various coal fields are being utilized.

By-product coke is now being made in the following states: Massachusetts, New York, New Jersey, Pennsylvania, Maryland, West Virginia, Alabama, Kentucky, Michigan, Indiana, Illinois, Wisconsin, Missouri, Minnesota, Tennessee, and Washington. Plants are also being built by the Koppers Company in Colorado and Rhode Island—eighteen states in all. Of these, only six—Alabama, Colorado, Ohio, Pennsylvania, Tennessee, and West

[8] *Iron Trade Review*, January 15, 1914.

Virginia—were coke producers of magnitude before the advent of the by-product oven. Together with this tendency to distribution, there is also an effect of concentration which is important. The effect in transplanting the business of coke manufacture from more or less secluded mining districts to important industrial centres is very marked. Two-thirds of the by-product coke producing capacity of the United States (including ovens under construction) is located within two hours' ride of one or another of

FIG. 9.

Coke from unmixed coal, Pittsburgh seam, Marion County, W. Va.

five large cities: Chicago, Pittsburgh, Cleveland, Detroit, and Birmingham. The amount of by-product coke capacity in these five metropolitan districts exceeds the total coke (beehive and by-product) made in the United States in 1900.

The intensive concentration of plant capacity made possible by the by-product coke oven is especially noteworthy. A striking example is the plant being built by the H. Koppers Company for the Carnegie Steel Company at Clairton, Pa. This plant, the largest in the world, will soon be put into operation with 640 ovens, having a capacity of 4,000,000 tons of coal per year. The plans provide for an extension of this plant to a total of 24 batteries of 64 ovens each. Some data as to the capacity and production of such a plant are as follows:

Annual Capacity of 1536 Ovens.

Coal	9,600,000 tons.
Coke	6,720,000 tons.
Tar	80,640,000 gallons.
Ammonium sulphate	110,880 tons.
Surplus gas	60,480,000,000 cubic feet.
Benzene	16,800,000 gallons.
Toluene	4,032,000 gallons.

This great plant, when completed, will have a coking capacity equivalent to 11,200 beehive ovens (one 12-foot beehive oven producing 600 tons of coke per year). In ordinary double-row construction (120 beehive ovens to a block 900 feet long) this

FIG. 10.

Coke from unmixed coal. Lower Kittanning seam, Fayette County, Pa.

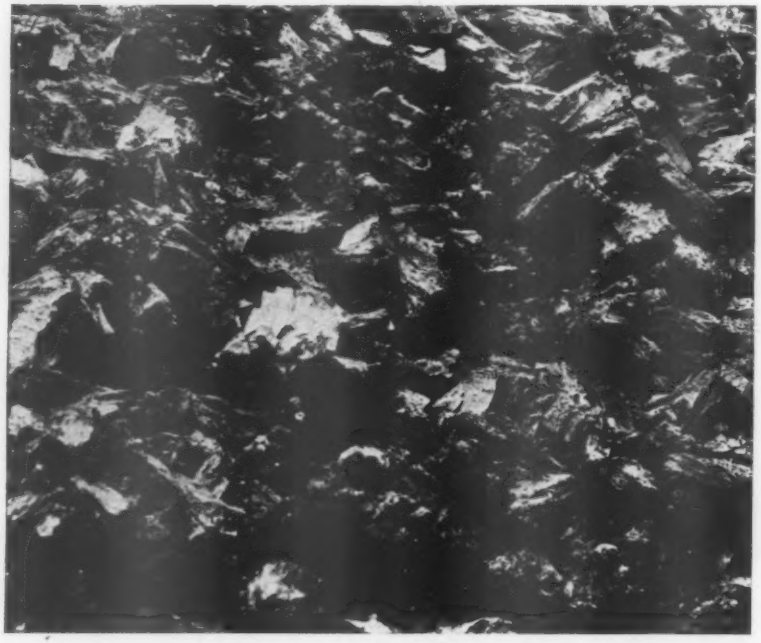
would make 16 miles of beehive ovens. The by-product plant, including some vacant space, is only 1500 yards long and 1200 yards wide.

The sources of the coal now being used for by-product coking are remarkably localized. The great bulk of the supply comes from the bituminous and semi-bituminous beds of the Appalachian trough as mined in Pennsylvania, Virginia, West Virginia, Alabama, and eastern Kentucky. Although some by-product coke has been made from Illinois and Indiana coals, and an important plant will soon begin operation upon Colorado coals, the enormous reserves of good coking coals in the interior, Rocky Mountain,

and Pacific coast provinces have scarcely been touched by the by-product oven in a commercial sense.

The present tendency is to use less of the expensive semi-bituminous coals—Pocahontas, Somerset, etc.—and to coke mixtures containing much larger percentages of bituminous coals, the volatile matter in such mixtures being from 30 to 35 per cent. The percentage of low volatile coal runs in usual practice

FIG. 11.



Coke from unmixed coal, Lower Kittanning seam, Preston County, W. Va.

from 15 to 30 per cent. Very fortunately it happens that not only do such high volatile mixtures produce larger recoveries of by-products, but the coke itself is usually found to give better results in the blast furnace, the decrease in coke consumption per ton of pig iron being in several cases quite marked. Fig. 3 shows coke of an excellent quality now being regularly made by the Koppers ovens of the Minnesota By-Product Coke Company from a mixture of Pittsburgh and Elkhorn coals, containing no low volatile coal whatsoever.

Of the commonly used bituminous coals, the most important come from the Pittsburgh, Freeport, and Kittanning seams in Pennsylvania and West Virginia, and from two or three remarkable seams in eastern Kentucky, of which the Elkhorn is the most conspicuous. H. A. Kuhn [9] estimated that in 1912, 75 to 80 per

FIG. 12.

Coke from unmixed coal, Elkhorn seam, Pike County, Ky.

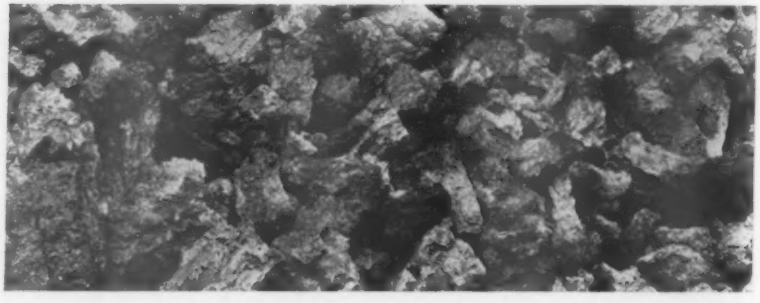
cent. of all the iron production of the United States was located tributary to the coking coal of the Pittsburgh district, and, although this condition has to some extent been modified by the subsequent enormous development of the new Kentucky coal fields, it is probable that the Pittsburgh district still holds the

[9] *Trans. Am. Inst. Min. Eng.*, 1914, p. 640.

lead over any other as a source of by-product as well as of beehive coke.

The study of the behavior of various coals in the coking process, of the quality of the coke produced, of the nature and yield of the different by-products, and, finally, of the adaptation of oven design and operation to produce the maximum value in by-products consistent with the manufacture of good coke, is a real science, the importance of which can readily be recognized. A description of the large organization and equipment devoted by the H. Koppers Company to this special science would make an interesting chapter in itself. It is this science that has made possible, during the last ten years, the rapid and at the same time

FIG. 13.



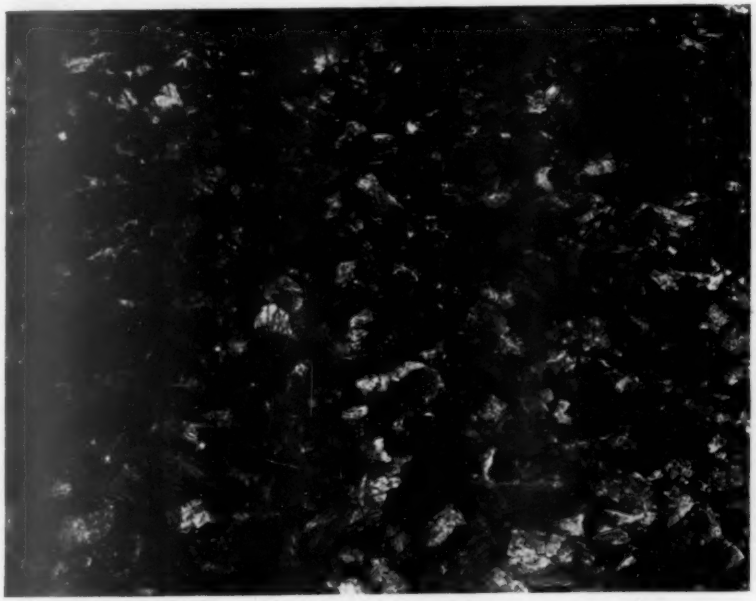
Coke from unmixed coal, Pulaski County, Ky.

steady progress in oven construction, without the hap-hazard design and costly alterations of the previous decade. The engineering feat of building a battery of coke ovens out of several different kinds of refractory materials, of most complicated and varying coefficients of expansion, so adjusted and coördinated that, although the total longitudinal expansion of the battery when heated to operating temperatures is nearly four feet, every oven wall is straight and every flue is gas tight—such a feat is being repeated so many times that we are apt to lose sight of the high degree of skill involved. Something possibly more remarkable is the uniform and correctly proportioned heating to temperatures ranging considerably over 2000° F., by gaseous fuel, of more than 700 square feet of interior wall surface per oven—or, let us say, 50,000 square feet in a battery of seventy ovens. Yet even such

accomplishments will often fail if we neglect the investigation of the coal which the ovens are expected to handle.

It is well known that the ordinary methods of laboratory investigation of coal—proximate and ultimate analysis, determination of calorific value, etc.—do not afford much assistance in obtaining information about the coking quality. From a general commercial standpoint some of them—*e.g.*, determination of ash,

FIG. 14.



Coke from mixed washed coals, Pueblo County, Colo.

sulphur, and phosphorus, composition and fusing point of the ash—are indispensable. All of them have their place in adding to the sum-total of our knowledge of coal, and the writer believes that anything, no matter how remote its apparent application, that adds to that knowledge will, in the long run, aid in a more thorough understanding of the coking quality. As has been shown by the painstaking work of Doctor White, of the United States Geological Survey, a study of the amount and nature of combination of the oxygen is especially promising in this connection.

No practical substitute has yet been found for the actual distillation of the coal under conditions simulating those that occur when it is coked on a large scale. This is not so easy as it sounds, because the conditions are very complicated, and very insignificant modifications of them in the laboratory lead to the most erratic results. The idea is widely prevalent that ammonia, tar, benzene, toluene, naphthalene, cyanogen, etc., are *in* the coal, the same way that iron is present in hematite or calcium oxide in marble, and that all the chemist has to do is to "analyze" the

FIG. 15.

Coke from mixed washed coals, Pierce County, Wash.

coal, to find out the amounts of these substances it will produce when coked in a by-product oven. Such an idea is far from the truth. Coal contains merely the elements that under certain conditions of heating may go together to form these and other substances; but it no more contains these substances originally than an acre of uncultivated soil contains wheat or potatoes. The amount of variation possible in the yields of by-products under different conditions is quite analogous to the variation possible in crops per acre of soil, depending upon fertilization, temperature, rainfall, etc. Most published results of laboratory coal distillations are on this account almost valueless for comparison with by-product coke-oven practice.

The extraordinary possible variations of quality and yields of by-products might make laboratory investigation seem almost hopeless, were it not for the fact that in almost every case we can fix one fundamental rule; namely, *by-products both in quantity and quality, must be conditioned upon the production of a satisfactory coke.*

FIG. 16.

Coke from unmixed washed coal, Nova Scotia.

In our methods for testing every sample of coal proposed for use in a by-product coke oven, the conditions of distillation are adjusted according to this rule; and we are able in each case to predict to a reasonable degree of certainty the behavior and products of any coal in our type of oven. The yields of by-products can be determined very satisfactorily by this method in the labora-

tory, but any estimate of the quality of the coke must be checked by an oven test. The oven test is desirable, not only to ascertain the character of the coke made under ordinary operating conditions, but also to determine how these conditions must be varied

FIG. 17.

Coke from mixture of 85 per cent. Pittsburgh + 15 per cent. Pocahontas coals. Made slowly in wide oven. Thirty hours' coking time. Appearance in oven.

in order to produce the best possible coke from the coal in question. As has been pointed out in a previous article, the possibilities of making coke conform to a desired standard, by proper preparation, oven construction, coking regulation, and, as a last resort, mixture with some other coal, are remarkably great—much greater, in fact, than is generally supposed. The mistake of

rejecting a coal for coke-making purposes on account of poor results obtained from a single test should be carefully avoided.

Some illustrations of cokes made from coals from a number of the best known American coal fields are given in Figs. 4 to 16. Figs. 5 and 6 are shown by courtesy of Mr. F. K. Ovitz, of the

FIG. 18.

Coke from mixed coal: 85 per cent. Pittsburgh + 15 per cent. Pocahontas. Made rapidly in wide oven. Sixteen hours' coking time. Appearance in oven. Note sponge in upper part.

United States Bureau of Mines, who has written a very interesting bulletin on coke from Illinois coals.[10]

These illustrations are characteristic of the fingery or "pebbly" coke that is very likely to be produced from a coking coal of high oxygen type. As a rule, such coals require more

[10] U. S. Bureau of Mines, Bulletin 138.

careful adjustment and regulation of conditions in order to produce a satisfactory coke than is necessary in the case of the commonly used coals of Pennsylvania and West Virginia, which contain about the same percentage of volatile matter, but less oxygen. A typical block of coke made from coals of the Pittsburgh district is shown in Fig. 4.

The other pictures show the various cokes as they appear on

FIG. 19.

Coke from mixture of 85 per cent. Pittsburgh + 15 per cent. Pocahontas coals. Made slowly in wide oven. Thirty hours' coking time. Appearance on bench.

the bench onto which the product of each oven is emptied from the quenching car. Fig. 16 is of some special interest because it shows an excellent coke made from a Nova Scotia coal which contains nearly 40 per cent. volatile matter. Each of these illustrations should be considered individually rather than as broadly typical, because the cokes were made at different plants and for different purposes, and were not intended for strict comparison. There is usually too much variation in the coking quality and by-product yields of coal from even a small district to admit of the presenta-

tion of "typical" samples or data, without the necessity of considerable latitude of judgment. There is sometimes as much variation from mine to mine on the same seam as from coal from two entirely different seams.

There is here a very interesting and virtually unexplored field, namely, the correlation of the geological relations of coals with

FIG. 20.

Coke from mixed coal: 85 per cent. Pittsburgh + 15 per cent. Pocahontas. Made rapidly in wide oven. Sixteen hours' coking time. Appearance on bench.

their coking qualities. There is no doubt that this subject is of great practical importance. A thorough knowledge of it would, for instance, enable us to estimate from simple geological considerations the value of a new mine on a known seam for by-product coking; or, on the other hand, would assist in defining an unknown seam in new territory from the results of laboratory coking tests. Our present knowledge, however, is much too meagre for this. There are a few outstanding facts which will be discussed briefly.

The geological age of a coal is no criterion as to its coking quality. As good by-product yields and as good coke are obtained from the comparatively recent coals of Colorado as from the early carboniferous strata of Pennsylvania. The coking properties of the Lower Kittanning seam undergo most remarkable changes parallel with the extent of devolatilization southeastward from Allegheny and Fayette counties, Pennsylvania, to the Potomac basin in Maryland. The phenomena of prime impor-

	Low-oxygen coking coals	High-oxygen coking coals
Examples	Appalachian bituminous coal fields	Illinois, Indiana, Washington
Shape	Blocky	Slender, tapered, fingery.
Hardness	Hard	Soft.
Exterior surfaces	Even	Sometimes smooth; but often having transverse seams or sometimes even masses of pebbly carbon.
Cell-structure	Regular—usually rather heavy cell walls.	Irregular—thin cell walls.
By-products: Gas	High yield—rich—little CO or CO_2.	Low yield—lean—much CO and CO_2.
Tar	High yield—thicker—high specific gravity—less tar acids.	Low yield—thin—lower specific gravity—more tar acids.
Ammonia	Normal	Often higher.
Benzol	Normal	Irregular.
Combined water	Low	High.
Rate of coking	Normal	Slow.
	The excess of fusible bituminous matter accumulates in the upper centre of the oven, forming a wedge-shaped, honeycombed mass, called "sponge."	Any excess of fusible bituminous material forms pebbly masses more or less loosely agglomerated and not always confined to the centre of the oven.

tance seem to be those of deoxidation rather than of devolatilization. The highly oxygenated coals of Illinois may have less volatile matter than coal from a portion of the Pittsburgh seam and yet produce a much inferior coke. In fact, the best basis we have for differentiation, with respect to coking quality, seems to have close relation to high or low oxygen content. We might make the above comparisons of these two kinds of coal with approximately the same percentage of volatile matter.

It would be very interesting to compare the results of normal geological deoxidation, such as has occurred in parallel undis-

turbed strata, like the Freeport, Kittanning, and Pittsburgh seams in Allegheny County, Pennsylvania, with what one might term "accelerated deoxidation," such as has occurred from the western to the eastern portions of the Lower Kittanning seam. Additional data must, however, be accumulated before we can begin to generalize on this subject.

The famous Pittsburgh seam is the most regular and dependable of any with which we have to deal. Even in this seam, however, the percentage of volatile matter drops gradually from about 37 per cent. in the western portion to about 27 per cent. in portions of the Connellsville basin. Attention has heretofore been given principally to this phenomenon of devolatilization, and it would be interesting to study the variation in coking quality from the standpoint of deoxidation. Here the differences in oxygen content are relatively smaller, and, in spite of the considerable range of volatile matter, we actually find comparatively small differences in the coking quality of different parts of the seam.

Figs. 17 and 18 show coke made from Pittsburgh coal + 15 per cent. Pocahontas in ovens of 20 inches average width, coked 17 hours and 30 hours respectively, heats having been adjusted to the coking time. Figs. 19 and 20 show the cokes from these ovens on the bench. Please note the difference in the amount of sponge, which is quite characteristic. The 17-hour coke, although it is smaller sized and more cross fractured, is stated to give excellent results in the blast furnace. In ovens somewhat narrower, such as those at St. Paul, and with a coking time of 19 hours, the Pittsburgh coal gives very little sponge.

The Elkhorn coal, the development of which in the last few years has been one of the prominent events in the coal industry, appears to occupy a position midway between the eastern high volatile coals and the more highly oxygenated coals of Illinois and Indiana. Its low ash and sulphur content and high by-product yields place it in the first rank of our best coking coals. It makes no sponge; but the coke shows some pebbly carbon like that characteristic of Illinois coals.

The data (Table V) showing the elimination of sulphur in coking various coals in by-product ovens are of considerable practical importance. The figures for Alabama coals and for mixtures of Pennsylvania with West Virginia, and Pennsylvania with Kentucky coals are each averaged from a large number of tests;

the other figures are from individual tests. Please note the high percentage expelled in coking Pittsburgh coal and the lower percentage from the higher oxygen coals of Washington and Kentucky. J. R. Campbell[11] has observed the higher percentage of sulphur elimination in the by-product oven, and states that in beehive practice they figure on about 20 per cent. elimination.

Sulphur Elimination in Coking Coals in Koppers Ovens.

State	County	Seam	Coking time hrs.	Coke yield per cent.	Sulphur			
					Per cent. in coal	Per cent. in coke	Per cent. of total eliminated	Per cent. of total retained
Colorado	Pueblo and Gunnison	.....	21.5	74.0	0.68	0.57	38.0	62.0
Colorado	Pueblo and Gunnison	.....	19.0	74.0	0.58	0.52	34.0	66.0
Colorado	Pueblo and Gunnison	.....	19.5	73.0	0.51	0.47	32.7	67.3
Colorado	Pueblo and Gunnison	.....	20.0	75.5	0.58	0.53	31.4	68.6
Colorado	Pueblo and Gunnison	.....	18.0	73.0	0.58	0.54	32.0	68.0
Colorado	Pueblo and Gunnison	.....	19.5	74.0	0.63	0.40	53.0	47.0
Alabama	Jefferson	.....	18.0	75.0	0.99	0.84	36.4	63.6
Alabama	Jefferson	.....	18.0	75.0	1.07	0.92	35.5	64.5
Alabama	Jefferson	.....	18.0	75.0	0.99	0.99	25.0	75.0
Alabama	Jefferson	.....	17.0	75.0	0.79	0.64	32.3	60.7
Alabama	Jefferson	.....	18.0	75.0	1.39	1.17	36.8	63.2
Alabama	Jefferson	.....	18.0	75.0	1.17	1.06	32.0	68.0
Alabama	Jefferson	.....	18.0	71.0	1.25	1.23	30.2	69.8
Pennsylvania	Allegheny	Pittsburgh	20.0	70.0	1.12	0.84	47.5	52.5
Pennsylvania	Fayette	Pittsburgh (Klondike)	17.0	68.0	1.03	0.95	37.3	62.7
Pennsylvania	Fayette	Pittsburgh (Klondike)	19.0	68.0	1.03	1.00	34.0	66.0
Pennsylvania	Westmoreland	Pittsburgh	19.5	71.0	1.85	1.50	42.4	57.6
Pennsylvania	Washington	Pittsburgh	20.0	72.0	1.06	0.76	48.3	51.7
Pennsylvania	Fayette	Lower Kittanning	19.0	75.0	0.87	0.75	35.3	64.7
Washington	Pierce	No. 6	17.5	70.0	0.60	0.58	32.2	67.8
Washington	Pierce	Mostly No. 6	19.0	70.0	0.53	0.46	39.3	60.7
Washington	Pierce	No. 7	19.0	76.0	1.70	1.57	29.8	70.2
Washington	Pierce	No. 8	19.0	72.0	0.46	0.49	35.8	64.2
Washington	Pierce	No. 8	17.5	72.0	0.54	0.51	32.0	68.0
West Virginia	Preston	Lower Kittanning	17.5	70.0	1.84	1.56	40.6	59.4
West Virginia	Marion	Pittsburgh	16.5	68.0	1.48	1.56	28.3	71.7
West Virginia	Marion	Pittsburgh	16.5	68.0	1.62	1.63	31.6	68.4

[11] *Trans. Am. Institute Min. Eng.*, 1916, liv, p. 181.

Sulphur Elimination in Coking Coals in Koppers Ovens.—Continued.

State	Mixtures with Pocahontas Coal	Coking time, hrs.	Coke yield, per cent.	Sulphur			
				Per cent. in coal	Per cent. in coke	Per cent. of total elimi-nated	Per cent. of total re-tained
Illinois	20 per cent. Illinois+80 per cent. Pocahontas	18.0	84.0	0.87	0.75	27.7	72.3
Pennsylvania	85 per cent. Pittsburgh (Allegheny Co.)	20.0	71.0	0.90	0.72	43.3	59.7
Pennsylvania	60 per cent. Pittsburgh (Allegheny Co.)	20.0	75.0	0.77	0.67	34.8	65.2
Pennsylvania	60 per cent. Pittsburgh (Allegheny Co.)	22.0	78.0	1.05	0.96	28.7	71.3
Pennsylvania	85 per cent. Pittsburgh (Fayette Co.)	21.0	71.0	1.07	0.81	46.4	53.6
Pennsylvania	70 per cent. Pittsburgh (Fayette Co.)	20.0	73.0	1.05	0.79	45.1	54.9
Pennsylvania	60 per cent. Pittsburgh (Fayette Co.)	20.0	73.0	1.03	0.76	46.2	53.8
Pennsylvania	20 per cent. Pittsburgh (Fayette Co.)	18.0	84.0	0.79	0.69	46.7	73.3
Kentucky	75 per cent. Pond Creek	20.0	75.0	0.55	0.49	33.2	66.8
Kentucky	75 per cent. Pond Creek	22.0	76.0	0.64	0.67	20.4	79.6
Kentucky	30 per cent. Elkhorn	20.0	80.0	0.69	0.68	21.2	78.8
Kentucky	75 per cent. Pond Creek	20.0	75.0	0.52	0.48	30.9	69.1

Projection Method of Testing Screw Threads. F. D. JONES. (*Machinery,* vol. 24, No. 8, p. 735, April, 1918.)—Considerable progress has been made in the development of apparatus for detecting inaccuracies in screw threads, especially during the past three years, because of the tremendous amount of screw cutting necessary in connection with munitions manufacture and the great importance of maintaining the screw-thread dimensions within the limits prescribed. Different types of gauges and precision measuring machines have been improved in design and new forms of apparatus originated. A modern and very effective method of testing screw threads is by the use of an optical projection apparatus. The principle is very simple: An image of the thread is projected upon a suitable screen and is then compared with the profile or outline of an accurate thread of standard proportions. It is necessary, of course, to determine previously the magnification or the extent to which the thread under observation is to be enlarged upon the screen, so that the profile or thread outline used as a standard in making comparisons may be drawn to a corresponding scale. This projection method shows errors in the pitch, angle, or form of the thread, and it is especially valuable for testing the shape of a

Whitworth thread. In order to secure a permanent record of the thread outline, the edge of the shadow projected on the screen may be traced in pencil upon a sheet which is filed for future reference. These outlines are sometimes sent to gauge-makers to show them the exact nature of the error, or to manufacturers when the outline is of a thread on the product instead of a gauge thread.

A photograph of the outline of a projected thread may be obtained without much difficulty instead of tracing the contour in pencil, although the latter method is simpler, more rapid, and less expensive. One method of securing a photograph is as follows: A part similar in form to the focusing bellows of camera is attached in front of the projector lens and is arranged to hold a plate slide. The exposure is made either on a rapid plate or directly upon bromide paper. A ground-glass screen is inserted in the plate slide prior to making the exposure, and is used for focusing. For comparative purposes the outline of a standard thread form may be secured in conjunction with the photograph of the thread to be examined by first making an artificial negative. This should be a duplicate of the standard thread, except that the outline is enlarged in proportion to the magnification of the projected thread image. A magnification of 20 is considered about right for making photographic reproductions. The artificial negative may be made by drawing as accurately as possible the thread contour on tracing paper. This outline, which should be twenty times the actual size of the thread, is next filled in with India ink to obtain a solid black thread section. Several coats of the ink should be applied, and, to prevent the paper from wrinkling and buckling, it should be moistened before applying the ink and then be smoothed out thoroughly after the ink is dry by using a hot flat-iron. This artificial negative is placed in contact with the sensitized plate preparatory to making the exposure, and it serves as a standard for comparing the photographic reproduction with the actual thread. The artificial negative must be set so that it will be parallel and close enough to the projected image to enable the actual and true outlines to be compared readily. The optical projection apparatus is not restricted in its use to testing screw threads, but may be employed to correct the accuracy of the profiles of gear teeth, the shapes of cams or gauges of the contour type, or any other parts having an outline that may be projected and compared with a standard form.

SOIL ALDEHYDES.*

A Scientific Study of a New Class of Soil Constituents Unfavorable to Crops, Their Occurrence, Properties and Elimination in Practical Agriculture.[1]

BY

JOSHUA J. SKINNER, Ph.D.

INTRODUCTION.

The isolation and identification of definite organic compounds from soils has stimulated investigations pertaining to the physiological effect of various organic compounds on plants. The chemical composition of the organic matter of soils concerns every investigator of soil problems: it may be the physicist, the chemist, the bacteriologist, the physiologist, or the agronomist. The quantity of organic matter in the average soil is considerable. The average content in the soils of the United States is 2.06 per cent., and of the subsoils, 0.83 per cent. (11).[2] The organic compounds which have been found to occur in soil organic matter affect plants differently: some are beneficial to plant life, others are inimical to proper plant development, and still others have no effect on growth. In every soil there exists a balance of these two contesting influences, the good and the bad. The decreased soil fertility, in so far as it is due to the chemical composition of its organic matter, as a single factor, is due to the preponderance of that type of biochemical action which will result in the accumulation of harmful compounds; increase in soil productivity, on the other hand, is due to favorable biochemical action resulting in the accumulation of compounds beneficial to plants. Whether one or the other predominates is due to soil conditions, drainage, composition, plant occupation, etc., which can be influenced by soil management, such as tillage, cultivation, drainage, liming, fertilization, and by crop rotation, all of which influence the biochemical factors in soils and, through them, soil fertility.

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* Communicated by Dr. Oswald Schreiner.

[1] Contribution from the Laboratory of Soil Fertility Investigations.

[2] Refers to literature citation in Bibliography appended.

During the last ten years a large number of organic compounds have been isolated from soils by Schreiner and his coworkers, Shorey, Walters, Lathrop, and Wise, of the Laboratory of Soil Fertility Investigations. Previous to that time the constituents of the organic matter of soils were practically unknown. The individual compounds isolated are agroceric acid (46), agrosterol (46), arginine (49), acrylic acid (61), adenine (61), benzoic acid (62), α-crotonic acid (82), creatinine (60), cyanuric acid (85), choline (61), cytosine (49), dihydroxystearic acid (46, 48), glycerides (49), guanine (42), hentriacontane (49), histidine (49), hypoxanthine (49), lignoceric acid (49), lysine (61), monohydroxystearic acid (49), metahydroxytoluic acid (62), mannite (61), nucleic acid (61), paraffinic acid (49), peptones (81), proteoses (81), pentosan (49), pentose (49), phytosterol (49), picoline carboxylic acid (47, 48), oxalic acid (61), rhamnose (61), resin (49), resin acids (49), resin esters (49), saccharic acid (61), salicylic aldehyde (61), succinic acid (61), sulphur (61), trimethylamine (61), tetracarbonimid (63), trithiobenzaldehyde (61), vanillin (62), and xanthine (49).

From this list it is seen that the compounds represent a great variety of chemical classes: there are paraffinic hydrocarbons, hydroxy fatty acids, and other organic acids, organic bases, esters, alcohols, aldehydes, carbohydrates, hexone bases, pyrimidine derivatives, purine bases, pyridine derivatives, organic sulphur compounds, organic phosphorous compounds, and nitrogenous compounds.

Especially interesting, in passing, are the groups of nitrogenous compounds. Some of these are beneficial and others harmful to plant growth; they are absorbed by plants as such, enter into the cell, and react with the protoplasm, causing effects either beneficial or detrimental, as the case may be. Among the beneficial compounds of this class which have been found in soils are creatinine (64, 65), creatine (64, 65, 10), hypoxanthine (54, 56), xanthine (54, 56), nucleic acid (54, 56), guanine (54, 10), histidine (54, 66), arginine, (54, 66), and choline (54). Other nitrogenous compounds reported as beneficial are acetamide (25), alanine (54, 25, 24, 31, 10), allantoin (54, 31), amygdaline (31), asparagine (54, 31, 24, 10), betaine (30), formamide (25), glycocoll (54, 25, 24, 31), and leucine (54, 31).

Not all nitrogenous compounds are beneficial, as is shown by

the following presentation: Guanidine (54, 55, 10), a nitrogen-containing body, is very harmful to plants. It is especially interesting in that it produces effects similar to those produced by plant diseases, manifesting itself by bleached spots on the leaves, which spread, cause wilting and final collapse. The effect is accentuated by nitrate, and is less observable in the total absence of nitrate. The striking difference between effects of the two closely related nitrogenous compounds, glycocoll and methyl glycocoll (54, 57), is also interesting. Glycocoll ($CH_2.NH_2.COOH$) is amido-acetic acid, and is one of the simpler degradation products found where decomposition is occurring. It exists in the tissue and seed of many plants. Methyl glycocoll ($CH_2.NH.CH_3COOH$) differs in its chemical structure from glycocoll, not only in that it contains the methyl group, CH_3, but also in that the amido group, NH_2, is thereby changed to an imido group, NH. It is not a simple protein body. Glycocoll is beneficial and is utilized as a source of nitrogen, while methyl glycocoll is also absorbed, but causes decreased growth and a peculiar twisted lateral growth of the leaf of the plant. Among other nitrogenous compounds which have been reported as harmful are aniline (30), aspartic acid (31, 43), atropine (30), barbituric acid (25), caffeine (30), carbamic acid (25), cocaine (30), diphenylamine (30), hexamethylene tetramine (25), hippuric acid (25, 31), morphine (30), myronic acid (31), naphthylamine (30), neurine (43), piperidine (43), pyridine (43), quinine (30), skatol (43), solanine (54), tetranitromethane, (25), theobromine (31), tyrosine (43), para urezine (25, 31), and uvitonic acid (48). Quinoline and pyridine (21) have recently been found by Funchess to be very beneficial to growth in soil culture, but this beneficial action is probably due to products of decomposition of the nitrogenous compounds, and not to the compound itself.[3]

Among other compounds which have interesting characteristic and contrasting effects on plants are cumarin, quinone, and vanillin (52, 53). Cumarin decreases growth and causes a shorter

[3] Since the preparation of this manuscript Funchess has shown that quinoline and pyridine nitrify in soils, quinoline nitrifying the more rapidly the more acid the soil. The nitrification of nitrogenous compounds was inhibited by aldehydes. (Funchess, M. J., "The Nitrification of Pyridine, Quinoline, Guanidine Carbonate, etc., in Soils," Alabama Exp. Sta., Tech. Bull. No. 3, Bull. No. 196, June, 1917.)

and broader leaf than is normal for wheat, and only the first leaves are usually unfolded, the other leaves remaining wholly or partially within the swollen sheath. The leaves that break forth are distorted, curled, and twisted. This characteristic development is not noticeable when the plants are grown in cultures containing considerable amounts of phosphates. The effect of quinone is decidedly different: it produces long, thin leaves and tall, slender plants. Potash ameliorates this effect to a large extent. Vanillin also produces thin, slender plants, but affects the roots more than the tops. It is interesting that the effects of vanillin are partially overcome by nitrate fertilizers.

In this paper the chief interest centres in the occurrence properties, and elimination of that class of soil constituents which partake of the nature of aldehydes. The results obtained in laboratory greenhouse and field with certain of these compounds will be presented, following a general discussion of the subject.

GENERAL DISCUSSION OF THE EFFECTS OF ORGANIC COMPOUNDS IN SOILS, ESPECIALLY SOIL ALDEHYDES.

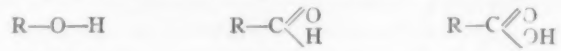
Compounds, or a mixture of compounds, having the properties of aldehydes have been found in many soils, but only three—salicylic aldehyde, vanillin, and trithiobenzaldehyde—have been definitely identified thus far, and this paper concerns itself principally with the effect of this class of compounds on plant life and their influence on soil fertility.

Salicylic aldehyde was first found in garden soils from the Mount Vernon estate, Virginia (61), and later was found in a number of other soils from widely different sections.

Materials having the odor of vanillin have been separated from a number of soils, but it was first separated in sufficient amount to identify from a Florida soil (62); it has been encountered quite frequently since in soils from other parts of the United States.

Trithiobenzaldehyde (61) was found first in a soil from California, but has not been encountered frequently.

It will be shown later that aldehydes are common in many soils, and especially in soils of low productivity. Alcohols and acids, the reduction and oxidation products of aldehydes,



Alcohols Aldehydes Acids

have been encountered in soils, which makes the study of the action of aldehydes on plants essential.

A review of the investigations on the action of aldehydes and other soil organic compounds on growth will be given here.

The earlier studies of the effect of soil organic compounds on growth was made in water-culture solutions. In the case of most of the compounds it was difficult to get sufficient quantities of the material to make exhaustive investigations of its effect on growth in soils. The absorptive power of some soils, together with their biological activities, affects added organic materials to such an extent that results are uncertain unless accompanied by tests to show the changes that the added substance may undergo. With water-culture experiments this difficulty is in part obviated. The experiments are made under better controlled conditions, and fewer factors enter into the results. While one should not draw definite conclusions from water-culture experiments as to what might take place under field conditions, yet it is impossible to study factors singly in the field, as must be done in scientific experimentation. The results secured in water cultures in this investigation have proved of vast importance; it would have been impossible to have shown that some of the nitrogenous compounds were used as such in plant metabolism without the use of water cultures. The field studies which are presented later are an outgrowth of the laboratory studies with water cultures.

Some recent investigators have objected to the use of water cultures in work of this kind, and have made experiments which should and do show that organic compounds having harmful properties do not exert as harmful an effect in soil cultures as in water cultures. They decry the use of such methods in soil and plant physiological investigations. It would be just as proper for the chemist to decry the use of C.P. reagents or the bacteriologist to disavow pure cultures as for the plant physiologist to decry the use of water cultures.

The first soil organic compound isolated, picoline carboxylic acid, did not prove to be harmful to plants except in high concentration (47, 48). Below 100 parts per million in distilled water it was slightly stimulating to wheat seedlings. Dihydroxystearic acid (46, 48), which has been found in soils, was very harmful to wheat in distilled water: in as low a concentration as 20 parts per million growth was materially reduced, and with 200 parts

per million the seedlings were severely injured. In nutrient solutions (50), composed of calcium acid phosphate, sodium nitrate, and potassium sulphate, the dihydroxystearic acid in concentrations of 50 parts per million also proved to be harmful. It was less harmful in the solutions composed principally of nitrate, showing that nitrate had an influence in changing its physiological effects.

Schreiner and Skinner have shown that a group of nitrogenous soil organic compounds are beneficial to growth and are absorbed and utilized by the plant as a source of nitrogen. Among these are creatinine and creatine (64, 65), nucleic acid (54, 56), hypoxanthine and xanthine (54, 56), guanine (54, 10), histidine and arginine (54, 56), and choline (54).

An extensive study of the soil aldehydes has been made and reported by Schreiner and Skinner. Salicylic aldehyde and vanillin (58, 67, 68) were first shown to be harmful to a number of plants in distilled water, in nutrient solutions, in some soils in pots, and in the field. Salicylic aldehyde affected growth much more than did vanillin. In the investigation with soils in pots it was found that the aldehydes were harmful in some soils and not in others. The soils in which these compounds showed no detrimental effect on plant development are good productive soils, with strong oxidation powers, and have good bacterial activity. The salicylic aldehyde was applied usually in amounts of 150 pounds per acre, and the vanillin 300 pounds per acre. It was further indicated that the aldehydes were not so harmful in limed soils, and that fertilizers had an action in ameliorating their harmfulness.

Experiments were made on three different soils in the field (70), each soil differing chemically, biologically, and physically, differing as to their crop-producing powers, and differing in that each was of a different origin and different geographical location. The salicylic aldehyde and vanillin were harmful in two of these soils, and had practically no effect in the third. On the Susquehanna silty clay loam, an unproductive soil on the Arlington Experimental Farm, Virginia, both aldehydes reduced the production of cow peas, garden peas, and string beans (58, 68). These soils were analyzed to determine whether or not the aldehydes remained in the soil as such throughout the growing period. The compounds were found in this soil six months after their application; that is, at the end of the crop season. It was further shown

that lime overcame the harmful effects of both aldehyde compounds, and that on this soil fertilized with phosphate the bad effects of salicylic aldehyde were greatly reduced, and on soil fertilized with sodium nitrate the effects of vanillin were lessened. The aldehydes did not persist in the fertilized soil. That aldehydes are harmful in some soils and not in others is probably accounted for by their inability to persist in soils having strong oxidizing powers and good biological activities. This is further demonstrated by the field experiments of Skinner and Noll (70) on the strong productive Hagerstown loam. On this soil the aldehydes were not harmful, and by chemical methods it was shown that the added substances were changed or destroyed in the soil.

Fraps (20) made some pot experiments with several soil organic compounds. He studied the effects of dihydroxystearic acid in soils. He states the material he used was impure dihydroxystearic acid. In an experiment growing corn (soil No. 1600) untreated pots produced 9.3 grammes and 10.1 grammes dry weight, while the pots to which dihydroxystearic acid in amounts of 500 parts per million were added produced 8.8 grammes dry matter, a reduction of 10 per cent. When calcium carbonate was added with the dihydroxystearic acid growth was reduced 42 per cent. The two untreated pots growing sorghum were very uniform. One produced 20.9 grammes dry matter and the other only 13.5 grammes, which makes a comparison of the treated pots rather uncertain. The dihydroxystearic acid treated pot produced 19.0 grammes dry matter, and the dihydroxystearic acid plus lime 19.9 grammes. It is rather unfortunate that a culture with lime alone was not included in this test; as it is, no comparison can be made.

In another soil (No. 1956) which had been fertilized with phosphate, nitrate, and potash, dihydroxystearic acid at the rate of 500 parts per million reduced the growth of corn from 18.0 grammes to 15.1 grammes of dry material, a reduction of 16 per cent. Dihydroxystearic acid with lime was still more harmful. In the experiment growing sorghum the average dry weight of two pots of the fertilized soil was 12.7 grammes, and that of the two pots with dihydroxystearic acid 10.5 grammes, a reduction of 18 per cent. Again, the dihydroxystearic acid with calcium

carbonate was more harmful, but no checks are included with the soil untreated or with lime alone.

The pot experiments with the aldehyde vanillin are also interesting and valuable in that he studied the persistence of the aldehyde in the different soils used in the experiment. In the experiments, adding vanillin in amount of 100 parts per million before planting, it was harmful in two soils out of nine used. When used at the rate of 200 parts per million it was harmful in each case. In other experiments the vanillin was supplied in fractional parts to the soil during the growth of the plant. In virtually all cases the growth of the plant was injured, except in the lower concentrations of 100 parts per million. Periodical application of this concentration injured the plants but did not kill them in the case of these Texas soils, in which vanillin disappeared rapidly. An examination of the results shows that the more rapid and complete the loss of vanillin in the soil the less is the injury observed in the growing plant. Thus his soil No. 3346 with vanillin showed a decrease in plant growth of 27 per cent. and a loss in vanillin in two weeks' time of only 24 per cent.; soil No. 4747 with vanillin showed a decrease in plant growth of about 14 per cent. and a loss of vanillin in two weeks' time of 60 per cent.; soil No. 4605 with vanillin showed a decrease of only 6 per cent. in growth but a loss of 71 per cent. in vanillin in two weeks' time.

Fraps's experiment with the effect of vanillin on three soils (Nos. 5101, 5649, and 1579) which had been fertilized with acid phosphate plus ammonium nitrate showed that the vanillin was extremely harmful to sorghum in each of these soils with the fertilizers applied. One hundred parts per million was injurious in two of these soils. Where 200 parts per million were added it killed the plants in one case and severely injured growth in the other two cases. Where 1000 parts per million were applied with the fertilizers, the plants were killed in every case. In another experiment in which he used seven soils, vanillin at the rate of 200 parts per million without and with acid phosphate and ammonium nitrate produced very injurious effects on the plants grown. In the experimental work of the present investigation, as will be shown later in this paper, acid phosphate did not overcome the bad effects of vanillin. No additional injurious action has been observed, however, when applied with this fertilizer. In the field experiments and with the soil in pots the

harmfulness of vanillin was lessened by sodium nitrate; nitrogen in the form of ammonium nitrate or in other forms was not used. Fraps's work seems to show that ammonium nitrate makes the vanillin even more harmful, indicating that some biological action takes place which produces conditions very bad for plant growth.

Fraps points out the well-known fact that these organic compounds are not as harmful in soils as in water culture, but seems to lose sight of the important results which his work so well demonstrates; that is, that these compounds act differently in different soils and under different conditions, and that they act differently because when formed or added they will remain in some soils and under some conditions, while they are destroyed in other soils.

Upson and Powell (76), working with a black silt loam of excellent texture and rich in organic matter, found that vanillin in amounts varying from 250 to 1000 parts per million had no effect on the growth of wheat plants in pots, but with another soil of equally good texture but less productive vanillin depressed growth slightly. Salicylic aldehyde in the same soil was somewhat more harmful, but it did not depress growth below 15 per cent. in any case. They conclude that aeration and absorption are important factors in overcoming the effects of the aldehydes, but give no experimental evidence. They made no attempt to ascertain whether vanillin or salicylic aldehyde existed in their soil for any length of time or whether it was destroyed.

Davidson (16) made some experiments with the effect of vanillin on wheat in pots in Dunkirk clay loam. He obtained practically no effect with added amounts of vanillin less than 1000 parts per million. With vanillin used in amounts of 1000 parts per million without fertilizers a depression of 10 per cent. in growth resulted, and the effect with the soil limed was about the same; with fertilizers the results were irregular. No attempt was made to determine if the added vanillin remained in the soil or whether it was changed or destroyed. These results do not agree with those of field experiments made on the Dunkirk silty loam reported in this paper, in which vanillin and salicylic aldehyde proved harmful to cow peas, even when fertilized.

Funchess (21) studied the effect of several organic compounds, among them the aldehyde vanillin, on crops grown in pots, in several soils. He presents no data showing the fate of

the compounds after their addition to the soil. Vanillin, in a Norfolk sandy loam, was quite harmful to oats in amounts of 500 and 1000 parts per million, but had only an indifferent effect in small concentrations. With a second crop grown after the harvesting of the first there was no residual harmful effect observed, indicating that the vanillin had been oxidized before the second crop was planted. A second application of vanillin before planting the third crop again caused considerable reduction in growth.

In another experiment, vanillin materially reduced the oats crop grown in this soil when used alone and with potash and phosphate and a complete fertilizer. Vanillin without fertilizers reduced green weight 66 per cent. with applications of 1000 parts per million and 42 per cent. with applications of 500 parts per million. Where the vanillin was used in pots with phosphates and potash the vanillin in amounts of 1000 parts per million reduced growth 69 per cent., and with 500 parts per million 50 per cent. Vanillin in pots with a complete fertilizer containing acid phosphate, sodium nitrate, and kainit, when added in concentrations of 1000 parts per million, reduced growth 40 per cent., and in 500 parts per million 32 per cent. While it appears from this experiment that the vanillin is slightly more harmful with phosphate and potash than in unfertilized soil, it is much less harmful in the soil fertilized with the complete fertilizer containing sodium nitrate. Funchess's results in the Alabama soil are in harmony with the results obtained by the writer on the action of this aldehyde in soils fertilized with sodium nitrate, previously reported. In the experiment with the Alabama soil the pots were planted to another crop, corn and cow peas, without any further addition of vanillin, but a second application of fertilizers was made. There was only a slight reduction in growth. This may be accounted for by oxidation or destruction of the vanillin, as four to five months intervened between the application of the aldehyde and the planting of the second crop. The alternate drying and wetting of the small volume of soil held by the pots, which in all probability occurred, would induce oxidation processes and thus change or destroy the vanillin. Again, in this work it is unfortunate that the absence or presence of the added substance was not determined from time to time during the experiments.

Other organic compounds were tested in the soil by Funchess, among them cumarin, which behaved somewhat as did vanillin, and dihydroxystearic acid, but they are not of interest in this paper dealing with the effects of aldehydes and therefore are not reviewed here.

Robbins (38) conducted some bacteriological experiments on the Alabama soils and secured results which seem to indicate that the disappearance of the added compounds vanillin, cumarin, pyridine, and quinoline was chiefly due to biological causes. The number of microörganisms increased greatly in the treated pots, following a depression in number which is analogous to that found in partial sterilization. The compounds added to sterile soils remained harmful to growth after a period of time, while the sterile soil which was inoculated with an infusion from normal soil showed no toxicity, the growth of the plants showing that the toxic properties of the compounds had largely disappeared. It is suggested by Robbins that the persistence of a compound—vanillin, for example—in some soils and not in others may be due to the fact that the vanillin-destroying organism is absent or to the fact that conditions are not suitable for its development or for the use of vanillin as a source of energy.[4]

Truog and Sykora (75) found vanillin, when added at the rate of 500 pounds per acre, in a sandy soil low in fertility and strongly acid in reaction, to be harmful to wheat grown in pots. Its harmfulness was overcome when the soil was limed, or when a complete nutrient solution was added. Vanillin added to a fertile silt loam produced no decreased growth. They also found guanidine to be very harmful. The effect of this strong basic compound was ameliorated by the addition of an acid kaolin to the sand culture. They concluded that chemical reactions are

[4] Since the preparation of this manuscript Floyd reports the results of some work with vanillin on citrus seedlings, in connection with investigations of the dieback of citrus fruits. In concentrations of from 39 to 1250 parts per million vanillin caused a shorter growth in stems and roots of grape-fruit seedlings; in the higher concentrations there was much surface injury of the roots. In amounts higher than 1250 parts per million there was much injury. The roots in all concentrations were discolored from a purplish brown to brown color. No gum was formed on the seedlings by the toxic action of vanillin (Floyd, B. F., "Toxic Effect of Organic Chemicals on Citrus," report of Florida Agricultural Experiment Station for 1916, p. 30 R.).

probably important factors in lessening the effects of harmful organic compounds in soils.

Thus, from the results of various investigations cited, it is seen that the effects of the soil aldehydes studied vary, depending upon the soil used and the method of study. However, it is shown that the aldehydes, salicylic aldehyde and vanillin, are harmful in soils in which they were not destroyed or changed by biological agencies. Before proceeding to give the detailed data showing the effects of the aldehydes studied, the results of a chemical examination to determine the occurrence and distribution of aldehydes in field soils will be presented.

OCCURRENCE OF ALDEHYDES IN GARDEN AND FIELD SOILS.

The discovery of salicylic aldehyde in the Mount Vernon gardens and the harmful properties of the aldehyde toward plants led to a study of the extent to which material of this type is likely to be encountered in soil investigations. In extending this study to many soils it was not feasible to examine large quantities of such soil, so that it was not possible to demonstrate clearly the identity of the aldehyde obtained, but it was possible so to treat a sample of soil as to obtain the compounds of an aldehyde nature contained therein, separated from compounds having non-aldehyde properties. This aldehyde material was tested as far as the quantity permitted for such reactions as are given by salicylic aldehyde; namely, coloration with ferric chloride, and the general aldehyde reaction with fuchsins reagent. In all cases the aldehyde material was subjected to the physiological test as to its effect on plant growth, using wheat seedlings in the well-known manner. The procedure employed in extracting the aldehyde material from the soil and the manner of testing it was as follows:

Twelve to sixteen pounds of soil were used in the examination for aldehyde. The soils were extracted with eight litres of a three per cent. solution of sodium hydroxide. The mixture was stirred for six to eight hours and, after settling over night, the liquid was poured off. The alkaline extract was acidified with sulphuric acid and filtered from the so-called humus precipitate. The acid filtrate was shaken out with several portions of ether, the ether extract combined and shaken with a concentrated aqueous solution of sodium bisulphite, which will remove aldehydes from the ether solution if present, by forming a water-soluble combina-

tion with the sodium bisulphite. The bisulphite solution was separated from the ether, strongly acidified with sulphuric acid, and air was blown through to remove the sulphur dioxide liberated. This acidified solution, in which the aldehyde is now liberated from its combination with the bisulphite, was then shaken with several portions of fresh ether, the ether extracts combined, and the ether removed by evaporation. There remained a small quantity of material, often resinous or oily in appearance.

This material was further purified by again taking up in water, extracting with ether, and the ether solution, after filtering, allowed to evaporate. Sometimes this operation was repeated. The purified residue contains the aldehyde material.

This aldehyde material was treated with a small quantity of water. The aqueous solution is frequently colored, and on evaporation a yellow oil is often noticeable, as would be the case if salicylic aldehyde were present. The odor of the latter is also sometimes observed, although in other cases other odors are perceptible, suggesting other aldehydes.

The fuchsine reagent was added to a portion of the solution, and to another portion a small amount of ferric chloride was added. Salicylic aldehyde, as mentioned, gives a violet color with ferric chloride and a pink color with the fuchsine reagent. Where both these reactions were observed the soil was considered as containing aldehyde. While the nature of the material is not thereby definitely shown to be salicylic aldehyde, yet the manner of isolation with ether and extraction therefrom with sodium bisulphite, together with the reaction shown with the fuchsine reagent, show the material to be an aldehyde, and the physical character of fluidity and the reaction with ferric chloride make it quite probable that in most of these cases salicylic aldehyde was under consideration. The amount obtained did not permit of further identification than is here given, especially as the main object was to determine the physiological property of the extracted material.

The main portion of the material remaining after making the above tests was dissolved or mixed with 250 c.c. of pure distilled water and the resulting liquid used as a culture for wheat seedlings in order to test the physiological effect of the extracted material from the soil. This was done with every soil examined, whether the above chemical tests were negative or positive.

In order to study the presence of aldehydes a number of soils were tested. Included in this test were a number of soils sent to this bureau from time to time by gardeners and greenhouse men. The soils submitted were garden and greenhouse soils, on which the owners had experienced some difficulty in producing vegetables or flowers. Often the soils had grown good crops, were intensively cultivated and heavily manured, and later failed. In this respect the conditions were similar to those on the Mount Vernon soil. This soil had been used for growing flowers and garden plants for a long time, had failed to show further response to manure, had been declining in productivity, and had been shown to contain salicylic aldehyde in the investigations reported. It seemed profitable, therefore, to include soils in this examination which in some degree had a similar history. The results of the examination of these soils, 14 in number, are given in Table I.

In addition to this adventitious examination of garden soils, a similar survey was made with soils collected in the open field by soil experts under instructions furnished them. Accordingly, samples of field soils were collected from various parts of the United States. A productive sample and an unproductive sample of the same soil type, either from the same field or at least in the same vicinity, were sent in for investigation. The history of the soils as to crops grown, fertilization, drainage, etc., was secured so far as available.

The result of this examination for the occurrence of aldehyde compounds in soils includes good and poor samples from many parts of the United States, comprising acid, neutral, and alkaline soils, soils of different cropping, different texture, drainage conditions, climatic conditions, etc. The results of the examination of these soils are given in Table II.

A total of 74 soils is described in the two tables. Of these, 14 are garden and greenhouse soils which had failed to grow good crops, and 60 are field soils under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. In this connection, attention should again be called to the fact that the field samples were collected in pairs, one good and the other poor, of the same soil type and from the same field or locality, so that statements concerning productivity pertain to the relation existing between the samples of the same type.

TABLE I.

Results of Examination of Unproductive Garden Soil for Aldehydes.

No.	Soil	Location	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat	
1	Garden soil, loam	Mount Vernon, Va.	Flowers	Acid	+	Very harmful	Rich loam, well manured for over a century.
2	Garden soil, silt loam	Mechanicsburg, Pa.	Vegetable	Very acid	+	Very harmful	Poultry manure and commercial fertilizer used for 10 years.
3	Garden soil, loam	Washington, D. C.	Flowers	Acid	−	No effect	Heavily manured.
4	Garden soil, loam	Pittsburgh, Pa.	Flowers	Acid	−	−	Manured, responds to lime.
5	Garden soil, gray sandy loam	Philadelphia, Pa.	Garden crops	Acid	−	Harmful	
6	Garden soil, loam	Phœnixville, Pa.	Garden crops	Alkaline	−	No effect	Well manured, salt content high
7	Garden soil, red loam	Orange, N. J.	Vegetables	Acid	+	Slightly harmful	Rich loam, declining, manure ineffective.
8	Truck soil	Chester Co., Pa.	Truck crops	Alkaline	+	Very harmful	Commercial fertilizer and rotation, trucked for 20 years, crops now failing. Soil contains excess of salts (0.15 %); sub line also contains aldehydes.
9	Greenhouse soil loam	Arlington, Va.	Flowers	Neutral	+	Very harmful	Heavily manured.
10	Greenhouse soil loam	Arlington, Va.	Flowers	Neutral	−	No effect	Soil weathered for months since it had been used for floriculture.
11	Greenhouse soil raw loam	Arlington, Va.		Acid	−	No effect	Raw soil used in making soils Nos. 9 and 10.
12	Garden soil gray	Philadelphia, Pa.	Garden crops	Alkaline	−	No effect	Drainage poor.
13	Garden soil waxy black	Green Co., Ind.	Garden crops	Acid	−	No effect	Responds to lime and potash fertilizer.
14	Dark gray	Sanford, Fla.	Citrus	Alkaline	−	No effect	Calcareous soil.

TABLE II.

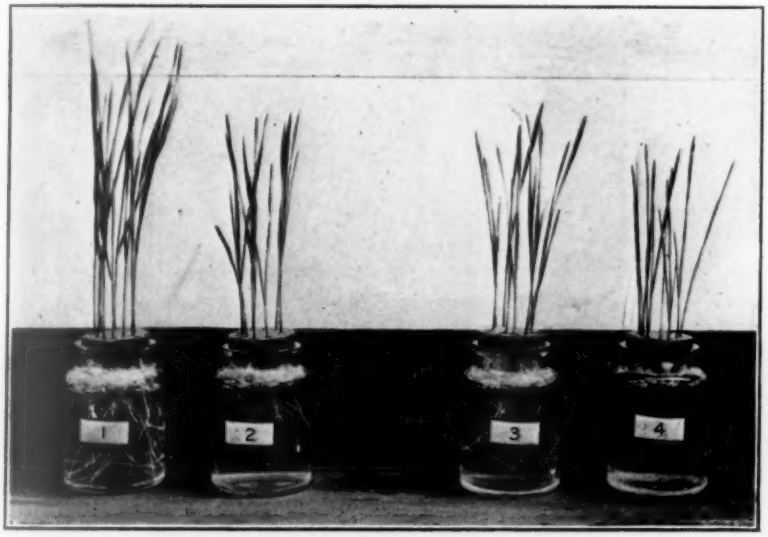
Results of Examination Productive and Unproductive Field Soils for Aldehydes.

			Productive				Unproductive			
No.	Soil type	Location	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat	Crop on soil when sample was taken	Reaction of soil	Presence (+) or absence (−) of aldehyde	Effect of extracted substance on growth of wheat
1	Tifton sandy loam	Covington Co., Ala.	Corn	Slightly acid	−	Harmful	Corn	Slightly acid	−	Harmful
2	Huntington fine sandy loam	Pope Co., Ark.	Corn	Slightly acid	−	Slightly beneficial	Corn	Slightly acid	−	Slightly beneficial
3	Decatur clay loam	Chattooga Co., Ga.	Cotton	Acid	−	Not tested	Cotton	Acid	−	Not tested
4	Noesloe silt loam	Cherokee Co., Kan.	Wheat	Slightly acid	−	Beneficial	Corn	Slightly acid	−	Beneficial
5	Colby silt loam	Jewell Co., Kans.	Corn	Neutral	−	Beneficial	Wheat	Neutral	−	Beneficial
6	Osage loam	Greenwood Co., Kans.	Grass	Alkaline	−	Beneficial	Corn	Alkaline	−	Beneficial
7	De Kalb silt loam	Christian Co., Ky.	Clover	Neutral	−	No effect	Tobacco	Neutral	−	Slightly harmful
8	Miami loam	Genessee Co., Mich.	Grass	Slightly acid	−	Harmful	Wheat	Slightly acid	−	Harmful
9	Carrington silt loam	Goodhue Co., Minn.	Barley	Slightly acid	−	Beneficial	Grass	Slightly acid	−	Beneficial
10	Memphis silt loam	Lafayette Co., Miss.	Corn	Neutral	−	No effect	Grass	Acid	+	Very harmful
11	Summit silt loam	Cass Co., Mo.	Oats	Not tested	−	No effect	Wheat	Not tested	−	No effect
12	Aurora silt loam	Miller Co., Mo.	Corn	Slightly acid	+	Harmful	Millet	Slightly acid	−	No effect
13	Freehold loam	Monmouth Co., N. J.	Grass	Slightly acid	−	Beneficial	Corn	Slightly acid	−	Slightly harmful
14	Dutchess silt loam	Orange Co., N. Y.	Millet	Neutral	−	Slightly harmful	Grass	Neutral	−	Harmful
15	Norfolk very fine sandy loam	Pender Co., N. C.	Cotton	Acid	+	Harmful	Cotton	Acid	+	Very harmful
16	Champlain loam	Ashe Co., N. C.	Corn	Neutral	−	No test	Corn	Neutral	−	No test
17	Toxiway fine sand	Ashe Co., N. C.	Grass	Slightly acid	−	Harmful	Grass	Slightly acid	−	Harmful
18	Portsmouth silt loam	Perquimans Co., N. C.	Cotton	Slightly acid	−	Harmful	Corn	Slightly acid	+	Harmful
19	Miami stony loam	Oneida Co., N. Y.	Corn	Acid	−	Slightly harmful	Meadow	Acid	+	Harmful
20	Ontario loam	Oneida Co., N. Y.	Oats	Neutral	−	Slightly harmful	Corn	Neutral	+	Harmful
21	Muskogee silt loam	Muskogee, Co., Okla.	Peanuts	Acid	−	Beneficial	Cotton	Acid	+	Harmful
22	Berks shale loam	Lehigh Co., Pa.	Grass	Slightly acid	−	No effect	Grass	Slightly acid	−	No effect
23	Norfolk fine sandy loam	Georgetown Co., S. C.	—	Slightly acid	−	No effect	Corn	Acid	+	Harmful
24	Clarksville silt loam	Robertson Co., Tenn.	Wheat	Acid	−	No effect	Clover	Acid	−	No effect
25	Jordan loam	Cache Co., Utah	Oats	Alkaline	−	Beneficial	Oats	Alkaline	−	Beneficial
26	Salt Lake clay	Cache Co., Utah	Wheat	Alkaline	−	Slightly harmful	Wheat	Alkaline	+	Harmful
27	DeKalb silty clay loam	Preston Co., W. Va.	Grass	Slightly acid	+	Harmful	Fallow	Slightly acid	+	Harmful
28	Carrington silt loam	Dane Co., Wis.	Tobacco	Neutral	−	Harmful	Oats	Acid	−	Harmful
29	Sioux fine sandy loam	Buffalo Co., Wis.	Corn	Slightly acid	−	No effect	Rye	Slightly acid	−	No effect
30	Miami silt loam	Jefferson Co., Wis.	Corn	Neutral	−	Harmful	Alfalfa	Neutral	−	Harmful

These soils were all subjected to the method described for obtaining aldehyde compounds from soils, and the material thus obtained tested with the reagents mentioned. Five of the garden soils and twelve of the field soils gave an appreciable amount of aldehyde compounds when thus extracted, and this material gave positive reactions with the fuchsine reagent and with the ferric chloride.

An examination of the data in Tables I and II shows that the aldehyde from certain of these soils is harmful to growth, and

FIG. 1.



Effect of salicylic aldehyde extracted from Mount Vernon garden soil on wheat seedlings: (1) Nutrient solution; (2) nutrient solution plus salicylic aldehyde; (3) distilled water; (4) distilled water plus salicylic aldehyde.

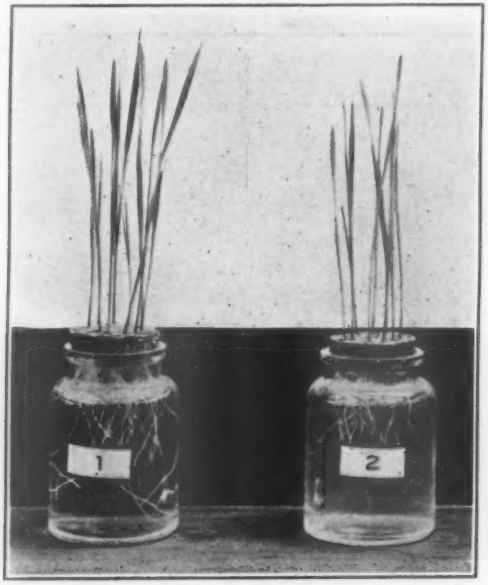
that these soils behave in this respect like the Mount Vernon soil (Table I, No. 1, Fig. 1), which has been already more fully described and in which salicylic aldehyde of poisonous properties was demonstrated.

In Fig. 2 is shown the effect of this material from soil No. 2, Table I. This has been used for gardening and trucking for the last ten years, and has been manured each year with poultry manure and commercial fertilizers. The soil in the last two years produced poor vegetables and truck crops, and corn failed en-

tirely. The soil is grayish-yellow in color, is quite acid and low in organic matter. The separated aldehyde extract was harmful to the growth of wheat seedlings, causing a decrease of 33 per cent.

In Fig. 3 is shown the effect of the aldehyde extract from soil No. 8, Table I, showing an alkaline reaction. This soil had been growing vegetables and truck crops for 20 years with frequent use of commercial fertilizers. Corn, cabbage, and canta-

FIG. 2.



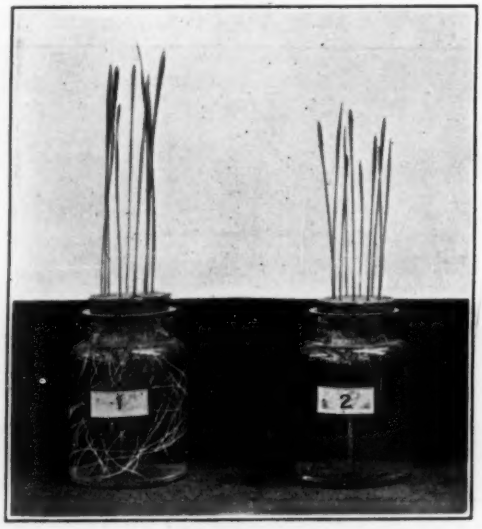
Effect of aldehyde extracted from garden soil (No. 2, Table I) from Mechanicsburg, Pa., on growth: (1) Distilled water; (2) distilled water plus aldehyde.

loupes had failed in certain sections of the field for the last two years, whereas formerly the soil grew excellent truck crops of all kinds. The soil and subsoil were quite alkaline to litmus paper, and both showed the presence of considerable aldehyde material. This aldehyde reduced growth of the test plants by 26 per cent., both tops and roots being severely injured.

The heavily manured greenhouse soil (No. 9, Table I) is particularly interesting in that considerable aldehyde was found, whereas neither the raw soil (No. 11, Table I) nor similarly

treated soil which had been used and then weathered for some time (No. 10, Table I) contained the harmful aldehyde material. This examination was made because the soil in question had been used on benches for floriculture and did not give good results. Soil No. 9, Table I, was a composite taken from two benches in the greenhouse where carnations and roses did not thrive. This contained aldehyde, which, when tested with wheat seedlings, gave reductions in growth of 35 per cent. Soil No. 10, Table I, had been previously used for greenhouse purposes and had been

FIG. 3.



Effect of aldehyde extracted from a poor garden soil (No. 8, Table I) on wheat seedlings: (1) Distilled water; (2) distilled water plus aldehyde from garden soil.

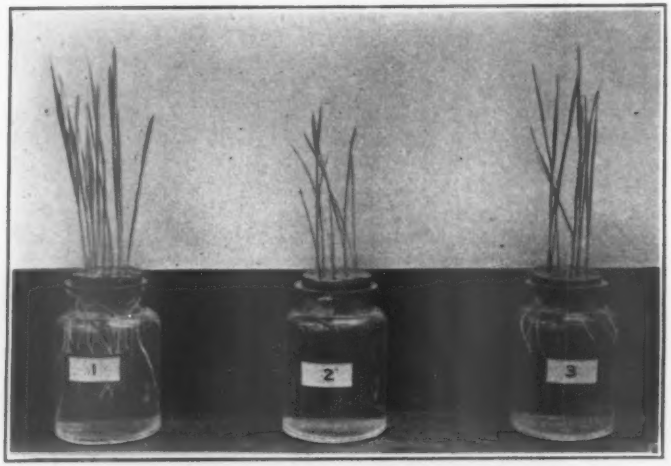
made in the same way by manuring heavily the raw soil, but without experiencing any difficulty. Since then it had been in a pile outside for several months. At the time of testing no aldehyde could be found, nor was the residue obtained harmful to the seedling wheat. Soil No. 11, Table I, was the raw soil as it was hauled from the field prior to the incorporation of manure in preparation for greenhouse use. No aldehyde could be detected in this soil, nor did such residue as was obtained show any harmful effect.

Soil No. 19, Table II, the unproductive sample of Miami stony

loam, contained aldehyde, and the depressed growth obtained is shown in Fig. 4, together with the effect of the identically extracted good field sample. The latter showed no aldehyde reactions, but, as seen from the photograph, it was, nevertheless, somewhat harmful—a fact which is recorded in the table.

Soil No. 20, Table II, the Ontario loam, unproductive, from Oneida County, New York, together with its good companion sample, presents an interesting story. In 1907 both fields were poor, unproductive soils. Both fields were manured heavily every year. One field responded to this treatment, the other did not.

FIG. 4.



Effect of substance extracted from poor and good Miami stony loam (No. 19, Table II) on wheat plants: (1) Distilled water; (2) distilled water plus material from poor soil containing aldehyde; (3) distilled water plus material from good soil showing no aldehyde reactions.

The field now good, represented by the productive sample, grew corn in 1907 and produced a poor crop. In 1908 the field was manured and planted to oats, giving a good yield. It was manured every year after this. In 1909 and 1910 hay was grown with good results, the largest crop being in 1910. In 1911 an excellent crop of corn was grown, and in 1912 oats were again grown with good yields.

The other field represented by the unproductive sample was in meadow in 1907 and gave poor yields. In 1908 the field was manured and planted to corn, which failed entirely. It was

manured every year after this without good results. In 1909 oats were planted, but made very little growth. In 1910 and 1911 grass was sown and gave poor results. In 1912 the soil was heavily manured and again planted to corn. The yield of stover was very poor, and no grain was formed.

The laboratory examination of the two soils showed them to be neutral in reaction. The good soil gave no reactions for aldehydes when extracted for this purpose, but the extracted material was slightly harmful. The poor soil, however, gave considerable amounts of aldehyde material, and this was distinctly harmful to the wheat seedlings, reducing growth 28 per cent.

The unproductive sample soil No. 26, Table II, the Salt Lake clay, is from a poor spot in an otherwise good field. The remainder of the field is represented by the productive sample of soil No. 26, Table II, and was collected about 35 feet from the poor spot. The color of the soil in the poor spot is light gray, while the good soil is gray with a pink tint. This spot is generally bare and seldom produces a crop, while the remainder of the field is very productive, yielding from 20 to 30 bushels of wheat per acre. The drainage in the poor spot is poorer than in the remainder of the field. The subsoil of both good and poor soil is a light, calcareous clay. Both soils are alkaline in reaction, and both showed the same content of water-soluble salts (0.03 per cent.). The good sample contained no aldehydes, and such residue as was obtained proved only slightly harmful to wheat seedlings, whereas the poor sample contained considerable aldehydes, which proved very harmful to wheat seedlings in the cultural tests, reducing growth 30 per cent.

Returning now to a discussion of the data as a whole, it is shown that the aldehyde extract is uniformly harmful to the test plants. This is apparent from the next to the last column of Table I and the fifth and last column of Table II.

In the tables are also given the field record of the soils as to their productivity, the data being furnished by the collector. The garden soils (Table I) were all soils with which trouble of one kind or another had been experienced. In general, the data show that the soils containing the aldehyde were also poor soils in garden and field, with some few exceptions. One notable exception is found in the Aurora silt loam, good (No. 12, Table II), from Miller County, Missouri. This soil contained aldehyde,

whereas the corresponding poor sample from another farm gave no indication of the presence of aldehyde. This observation was confirmed by procuring a new sample from the farmer on the good soil six months later. The other exceptions are the Norfolk very fine sandy loam, good (No. 15, Table II), and the Dekalb silty loam, good (No. 27, Table II), in which aldehyde was found, but it will be noticed that in both cases the poor soil contained the aldehyde also. It would appear, therefore, that both the good and poor soil samples contained some aldehyde. It might be further pointed out that in both cases the greater productivity of the sample designated as good is doubtless due to the direct fertilizing value of the applied manure, the less productive samples having no manure applied. That manure is not antagonistic to aldehyde is indicated by its presence in the exceedingly well-manured garden soils (Table I) (see notes in last column), as well as by some of the field results.

From these two tables it is at once apparent that only a relatively small number of the poor soils showed the presence of aldehydes, which means that the poorness of many of the soils must be attributed to other causes, since soil infertility may be due to a great many factors other than the presence of toxic compounds, and especially any particular toxic compound.

The material extracted in the aldehyde method, as in all these cases, was extremely small and gave no aldehyde reactions, but in some cases it proved harmful, nevertheless. What the nature of the harmful substance in these cases was it is impossible to state, as further study was excluded. If aldehyde was present, it was at least so small in amount that it escaped chemical detection; nor does the method wholly exclude the occurrence at this place of traces of other compounds. In the majority of cases the material was not harmful, occasionally even showing a slightly good or stimulating effect.

Seventy-four soils are described in the foregoing tables. Of these, 14 were garden and greenhouse soils which had failed to grow crops, and 60 were field soils, under general farming conditions. Of these 60, 30 were productive soils and 30 unproductive. These soils were all examined for aldehydes. Of the 14 garden soils, five contained aldehydes, and of the 60 field soils, 12 contained aldehydes.

(To be continued.)

DYESTUFFS.*

BY

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MR. CHAIRMAN, LADIES AND GENTLEMEN:

IN addressing you this evening upon the subject of Dyestuffs, I am not unmindful of the wide extent of the subject and also of the very great amount of information and data, both general and technically special, that has been given to the public from various sources, since August, 1914.

During this intervening period, and particularly during its first twelve months, when there was manifested so much concern regarding the probable supplies of coal-tar colors for our several dye-consuming industries, the wildest rumors regarding the possibility of dye production in this country were current, and there was hardly a day but some new and far-reaching discovery was announced, in the columns of the daily papers, that would unlock the tightly-closed secrets of the German dye makers, and unlimited quantities of much-desired anilines would flow forth.

We know now that much of this wild publicity was the result of a total misconception of what dye production is, and the very great majority of those who were to relieve the serious dye situation are now at labor in other fields.

The dye industry, like many other fields of activity, has been developed by gradual stages through the years, and from the most modest beginnings. It has grown and increased in importance from the time when the artistic ideas of peoples were in a very crude state.

From the very earliest times of which we have record, there is evidence that certain coloring matters of organic origin were in use, the two most important being indigo and madder, and it is interesting to note that these two items have come down to us continuously to the present.

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* Presented at the Stated Meeting of the Institute held Wednesday, February 20, 1918.

It is not necessary to burden you with a list of those coloring matters quoted in the Scriptures, but it may be interesting to record the fact that in Europe, prior to 1600, the art of dyeing, even at that time had attained considerable importance on account of the skill of the dyers. There were currently employed at that period:

Indigo, Madder, Litmus, Brazil Wood, Lac Dye, Kermes, Buckthorn Berries.

These several dyewares, or the coloring matter extracted from them, were mostly used for dyeing woollen fabrics and linen.

During the long years between 1600 and 1860, there were gradual additions to this old list of natural colors, which then included besides Indigo, Madder, and the astringents—Sumac and Gallnuts—Peachwood, Camwood, Barwood, Sanders Wood (tropical woods); Cochineal (Guatemala); Fustic (Cuba); Weld Quercitron Bark (Pennsylvania); Cutch and Turmeric (Burma and Mexico). With this line of dyewares, the dyer was in a position to meet most of the demands made upon him for dyeing not only wool, but cotton and silk as well.

In certain localities, notably in parts of France, some coloring matters obtained from plants indigenous to the region in which the dyer worked, were used. Among these dyewares may be included safflowers and saffron, the former much employed for a most beautiful shade of pink, and the latter for a shade of yellow.

As the fame of the dyer's products and skill spread, the interest of dyers in other localities became excited and the desire to produce similar results was aroused. In consequence, the secrets of the dyer, handed down from father to son, were jealously guarded, so that competition might not be able to duplicate their work. We have evidence of this condition when we examine the recipes extant in old formula books of dyers of past generations, notably in the production of the so-called "spirits," those mysterious compositions of tin and certain acids, which were designated largely by misleading names.

The dyer of the period, prior to the introduction of the coal-tar dyes, was indeed a real master craftsman. While he may not have had the refined surroundings of the dyer of the present nor the highly developed scientific aids that are now so common, he produced results that are to be regarded as marvellous. When we read old notes and recipes, and bring to our mind the uncertain

composition of the various "infusions" that the dyer employed, we are compelled to acknowledge that the workman of the period was one who really knew his trade.

The "infusions" or "liquors" made use of at that time, were largely weak liquid extracts made by boiling the crude natural dyewares with water, then straining and using the stock solution as the dyer's demands required. At other times, such as for logwood, a given amount of the ground wood was simply boiled out, and the total amount of infusion so obtained was employed for one batch of material to be dyed. This crude method of operating was the origin of the now highly-developed logwood industry which flourishes both in this country and in Europe, especially in France, from which country, the very finest logwood extracts have come.

There were other natural dyewares analogous to logwood, which occupied a prominent position in the catalogue of active coloring matters, and which include peachwood, barwood, sanders wood, and other similar woods, the majority of which are natives of the tropics. They were chiefly used for producing red, brown and many compound shades upon wool in combination with logwood. These woods were imported and ground, and the ground or rasped wood was sold to the dyer, who made the infusions as his requirements called for. Some of these now scarce and curious dyewares were used in Philadelphia even as late as 1895, where they were employed for producing shades upon heavy carriage robes, and in dyeing seal plushes. From that time until the outbreak of the war, the decline in the use of those products was rapid and complete. When the war curtailed many of the artificial colors, the dyers had to fall back upon these antiquated coloring matters, and after a time, some were imported and sold at unheard-of prices on account of the great demand and scarcity of stock. Afterwards, when domestic producers of artificial colors began to make deliveries, the market for the older dyewares fell off again. It is curious to note, however, that during the "dyestuff famine," when these antiquated coloring matters were brought to light, very few dyers knew anything about their application, and, as a consequence, the dyed material that was delivered from mills did not measure up to the usual current standards for fastness, and therefore, dyes were condemned offhand, when, as a matter of fact, the fault was not with the

dyestuff, but with the inexperience of the dyer, due to his unfamiliarity with the dyestuff he was using.

There are to-day many experienced cloth dyers who are expert in the application of logwood—for be it remembered that logwood has always been a standard dyeware for black on wool, and against which artificial blacks for the same purpose are judged—and these same dyers are absolute failures when it comes to using other colors. The same remark applies with greater force to the dyeing of silk. There are no dyestuffs of coal tar origin that can duplicate the well made logwood blacks on this fibre. Black dyeing in the silk industry is a trade by itself, and deservedly so.

Indigo has been handed down to us from the earliest times as the one blue color that has been regarded as having a degree of fastness far in excess of any product yielding the same shade. It is a native of certain portions of the tropics of both hemispheres, but the greatest amount of natural indigo has by far been produced in British India.

Indigo, as it appears in commerce, is the blue coloring matter obtained by oxidizing the juices of the indigo plant. The plant at maturity is cut and carted to the indigo factory where it is placed in huge vats, water run on, and the whole allowed to ferment. At the proper stage of fermentation, the liquors containing the indigo in a chemically reduced state (indigo white) are run off and agitated, either by being whipped by hand or by revolving light paddle wheels. This agitation causes atmospheric oxidation of the indigo white, which is soluble, to indigo blue which is insoluble and precipitates. This precipitaton is then filtered and the cake pressed, then cut to proper size and branded while still moist, and finally dried. It is then ready for the market.

Indigo as a source of blue color, for textiles, has had an unbroken period of use for centuries. It is employed in dyeing both wool and cotton; the former by means of both so-called "vats" and as "extract," the latter always in the vat. Vat dyeing means that the indigo is reduced to the state of indigo white and then subsequently oxidized to indigo blue on the fibre. "Extract Blue" is dyed by means of a solution of indigo in sulphuric acid, formerly called "chemic," and in later years more carefully prepared by purifying the sulphuric acid solution of the indigo. A highly-refined dry indigo extract is sold as Indigotine.

but it is in reality only a disulphonic acid of indigotine—the real blue color of indigo in soluble form.

Madder is another of the natural dyewares that has been in use for centuries, being employed most commonly for the production of reds—the red which we are most familiar with being termed Turkey Red. Formerly, and up to the recovery in 1868 of artificial alizarine by Graebe & Lieberman, its cultivation and preparation for market was a most important and flourishing industry. When artificial alizarine became a commercial reality, the madder industry rapidly declined to very small proportions, and as a dyeware, it is no longer to be considered.

The several coloring matters to which I have directed your attention, occupying positions of first importance in the dyer's art, are mentioned for the purpose of preparing the way to the serious consideration of the dyes of artificial origin, and by which the great majority of the older dyes were completely displaced.

The first dyestuff of artificial origin is the well-known Perkins' Violet, and its discovery in 1856 paved the way for rapid strides in organic chemical research that has continued from that date to the present time, and the number of patents granted by various industrial countries attest the activity of chemists in the direction of dye production, although not every patent granted represents a dye that has attained commercial interest.

The more important artificial discoveries may be briefly summarized as follows:

Perkins' Violet or Mauvein	(Epoch) 1856	
Fuchsine or Magenta	1858	(Hofmann)
Aniline Black	(Epoch) 1862	(Lightfoot)
Nicholson's Blue	1862	
Methyl Violets	1866	(Poirrier)
Safranine	1868	
Artificial Alizarine	1868	(Graebe and Lieberman)
and its manufacture in	1869	
Indigo Blue from isatin	1870	
Eosine	1874	
Cachou de Laval (first sulphur color)	1873	
Triphenylmethane Dyes	1876	
Methylene Blue	1877	
Fast Red	1877	
Azo Scarlets	1878	
Propiolic Acid for Indigo	1880	
Congo Red (first direct or substantive color)	1884	

Tartrazine (first fast acid yellow for wool)..	1885	
Primuline and the "ingrain" colors	1887	
Carbazol Yellow	1888	
Diamine Fast Red F.....	1889	
The Thioflavines	1889	
Indigo from Phenylglycocol.....	1890	(Herman)
Cyanine	1891	
The Rhodamines	1893	
Vidal Black (first sulphur black).....	1895	
Synthetic indigo, vat colors, etc.		

This list could be greatly augmented but it is sufficient to indicate the gradual extent of industrial and chemical research that has developed the great number of dyes that find use in some or all of the industries employing coloring matters.

The particular branch of dye research that includes the so-called azo colors, deriving its impetus by the discovery of Peter Greiss in 1862, has been most productive of results and for the time engrossed the attention of the great majority of dye chemists, with the result that there were innumerable products given to dyers that traced their origin to the Greiss reactions. This particular group of dyes—Azo dyes—is chemically subdivided into thirteen divisions, and in their extension and development there has been made necessary a vast amount of chemical research covering the production of those raw materials that are necessary for each particular dye. This phase of dye chemistry has been to a very great extent neglected in this country, but during the past three years it has been receiving a degree of attention never before attempted in private laboratories, works' laboratories and in colleges.

In the operation of dye making, certain raw materials are necessary. These raw materials are obtained in the first instance from certain distillation products obtained from coal tar; the most important for the purpose of illustration are benzol and naphthalene.

From benzol there are obtained a succession of secondary products each the result of a definite reaction, and each possessing certain properties.

From naphthalene there are also obtained by various reactions a number of products aggregating at least one hundred and seventy-five, and each of which possesses properties that make it useful for certain further reactions. If we study the chemistry

of several of these benzol or naphthalene derivatives, we will at once be impressed with the immense amount of painstaking research work that must have been done in order to ascertain the properties of each product, and the possibilities of combining each of them with other dissimilar bodies, for the purpose of obtaining a dye or coloring matter different from any other before produced. It is this constant investigation that has been at the bottom of the seemingly endless array of known dyes.

If the dye chemist has only to give his attention to combining various raw materials, his work is extremely simple, but where he has to work out the production of new raw materials, then his work becomes extremely complicated.

In studying the chemistry of the commercially useful derivatives of naphthalene, mostly sulphonic acids, we are at once impressed with the limited sphere of labor undertaken by the investigators, and a digest of the patents will show that the labors of these investigators have been quite active within these limits. Each investigator has concentrated upon some one, or possibly two, groups of colors, and their necessary raw materials, leaving to others similar work along diverging lines.

The group of azo dyes includes the greater number of dyestuffs that are available for cotton and wool, and for a long time after the classical discovery of Peter Greiss, occupied the attention of many chemists, with the result that a very extensive range of colors were produced with which the dyer was enabled to obtain shades of almost every conceivable hue.

One of the most important discoveries was the production of the so-called azo scarlets, which, in a short time, completely displaced cochineal. These original scarlets were later considerably improved upon, and brilliant shades were made possible possessing extreme fastness to light. Several of these scarlets are much employed in other industries, notably for the staining of paper.

The ultimate production of wool blacks marked the beginning of a revolution in dyeing certain textiles, which were formerly dependent upon logwood, and in time, the gradual decline of this latter dyeware became quite noticeable.

It is unnecessary for me to dwell upon the technical details for the production of these various products, since the outlines of the most important may be found in many treatises and in the patent literature.

After the discovery of Congo Red, in 1884, there was an immediate concentration of chemical endeavors upon the group of substantive dyes—dyes that colored cotton without a mordant—the result being a long line of products that at once gained recognition throughout the world. Some of these dyes are remarkable from the fact that they are capable of dyeing corresponding shades upon both cotton and wool, thereby opening the way for a valuable line of dyes, known as "union dyes," with which both of these fibres may be dyed the same shade in the same bath. This is of great commercial importance, inasmuch as it permits the manufacture of cotton and wool mixed goods that were not theretofore possible, except with considerable trouble.

There are many wool dyes that partially stain cotton, and also many cotton dyes that only slightly stain wool. The dyer, therefore, has at his command the means, by a judicious admixture of these two classes of dyes, of producing a combination of dyes that will enable him to dye union goods with the greatest ease. Most of these combinations dye the cloth in a bath fortified only with a small amount of sulphate of soda.

One of the most important, far-reaching dye discoveries was that of an Englishman—Green—in 1887, who produced a series of dyes known as "ingrain colors," and which at once gained a strong foothold in cotton mills on account of the then remarkable fastness of the shades produced. The most important dye of this group is known as primuline, and occupies a prominent position to this day as a source of red for cotton. It was the first dye to serve as a substitute for alizarine on certain classes of goods. Primuline is dyed upon cotton by the so-called "three-bath" process, which provides for the diazotization of the color on the fibre and its final development with a suitable developer, the most common being beta-naphthol, and produces the red above referred to. This group of colors was first limited to a few shades, possibly six, none being either a blue or a black. This disadvantage was at once apparent, and stimulated research, so that in due time diazotized blacks and blues came upon the market. The blacks appeared to offer particular advantages, especially as competitors of aniline black for hosiery dyeing. Indeed, a number of the best known brands of hosiery on the market are dyed with developed black.

The industry of the sulphur colors commenced by Croissant &

Bretoniére in 1873 has been greatly extended, and from which has been given a great number of dyes of the utmost importance. Their field of usefulness is almost confined to the dyeing of cotton. The blacks of this group have, together with the diazotized blacks, been the active competitors of aniline black, while the sulphur blues have, in many instances, replaced indigo for certain lines of cotton manufacture. The sulphur color industry is actually the starting point of the now firmly established " vat color " industry, although but few of the vat colors are made by any of the processes used in producing sulphur colors. The extensive group of vat colors includes a considerable number of dyes that are remarkable for their extreme fastness, and it was the general use of these dyes that gradually educated the people as to what a really fast color is.

The so-called vat dyes are divided into two main groups designated respectively Indigoid dyestuffs and Anthrachinone. The chemistry of both of these two groups is rather complicated and it will serve no useful purpose by going into the details of the reactions. For convenience, however, the following classifications may be introduced:

(*a*) INDIGOID DYESTUFFS.
(1) Indigo Group,
(2) Ciba Violet Group,
(3) Thioindigo Group,
(4) Indi Rubin Group,
(5) Thioindigo Scarlet Group,
(6) Ciba Scarlet Group.

(*b*) ANTHRACHINONE DYESTUFFS.
(1) Indanthrene Group,
(2) Flavanthranone Group,
(3) Benzanthranone Group,
(4) Anthrachinonimide Group,
(5) Acylaminochinone Group,
(6) Anthrachinonacridone Group,
(7) Vat dyestuffs of unknown composition.

(*c*) VAT COLORS CONTAINING SULPHUR.
(1) Anthrachinone Bodies,
(2) Carbazol Bodies.

This particular group of dyestuffs has excited remarkable interest ever since they were put upon the market; not alone from the chemical standpoint, but also from the fact that the practical

results obtained from their use enabled manufacturers of cotton goods to greatly extend their line of woven and printed novelties, carrying at the same time a guarantee as to fastness and durability of shades that startled the industrial world in those lines of cotton manufacture known particularly as wash goods, ladies' and children's summer garments, men's shirtings, madras cloth and similar fabrics, carrying shades of blue, red, pink and combinations that emerged from the laundry quite intact. The study of the vat colors is most interesting. It should be borne in mind that the great majority of the patents granted for these particular colors are still in force and this fact alone is likely to mitigate against the possibility of the more important of the dyes so protected being manufactured in this country, even after the present war is terminated. There is every reason to believe that the German holders of patents for these valuable dyes will exert every effort to retain the manufacture of these dyes for and in Germany, and that it is hardly likely that licenses will be granted to American dye manufacturing plants permitting of the manufacture of even some of the most wanted of this group of colors. This condition, however, should not prevent a special effort being made on the part of dye chemists, professors of organic chemistry and advanced students of that particular branch of organic chemical work from devoting their undivided time and attention to the investigation of problems aiming to the production of further additions of dyes to this important group of colors. This is a most prolific field and one worthy of very serious thought on the part of chemists.

In this particular connection and relating very closely to this same group of coloring matters may be mentioned work done within very recent years. I take the liberty of making reference to a particular blue that requires as one of its chief raw materials a substance that has heretofore been regarded as an industrial nuisance, but which, due to the painstaking care of the investigating chemists, has been made available for the production of a coloring matter that possesses a shade equal to, and properties excelling in fastness those of indigo. I refer to carbazol, which, prior to this time, had been of no commercial or industrial value whatever, which has been found closely associated with anthracene as an impurity and from which latter it has to be separated by a process fraught with some difficulties. Carbazol has been

made available for textile purposes by being converted into the blue dye applied in a manner similar to indigo in the " vat," and which produces indigo shades from the lightest to the darkest with great facility. For its production it is simply a matter of obtaining carbazol and when this product is secured in sufficient quantities there is no doubt but that the dye industry and that portion of the textile industry most interested will receive a great impetus.

In mentioning carbazol as a prolific field for chemical investigation, I might also include a number of equally well known and troublesome organic impurities found in other coal-tar distillates, which only await the attacks of the painstaking industrial chemists to find ways for their commercial utilization.

At this point the lecturer directed attention to a number of illustrations, several of which are printed herewith. The first was a diagram of a coal tar tree showing the general relationship that the finished dyestuffs have towards coal tar. By this tree we immediately grasp the idea that upon the destructive distillation of tar, certain prime raw materials are obtained, which, when subjected to further chemical treatment, are converted into the so-called intermediates that the dye maker employs for the production of the finished dyestuff. Coal tar itself is a by-product of the destructive distillation of coal either from the illuminating gas making process or from other operations where tar is recovered. During the process of distillating coal, illuminating gas is obtained, and during the operation of washing this gas ammonia is recovered. The residue remianing in the gas retorts is coke. When coal tar itself is subjected to destructive distillation it breaks up into a large number of raw materials, including Benzol, Carbolic Acid, Cresoles, Naphthalene, Anthracene, heavy oils, and leaves a large residue of pitch, the exact composition of which is known to vary, but which is still a subject of fruitful investigation by chemists.

The next diagram herewith reproduced (Fig. 1) shows graphically the average percentage composition of coal tar. Each square represents one per cent. The small amount of phenol or carbolic acid actually present in tar is indicated as well as the small amount of anthracene. It is this small amount of anthracene that carries a small, though available, amount of carbazol, to which I have previously alluded.

Figure 2, herewith, is a diagram showing the average

quantity of distillates obtained from 2000 pounds of coal, together with the quantities of a few of the important dyestuffs which some of these distillates produce.

Figure 3 shows the sequence of events for the conversion of Benzol and Toluol into the well-known dyestuff magenta or fuchsine.

FIG. 1.

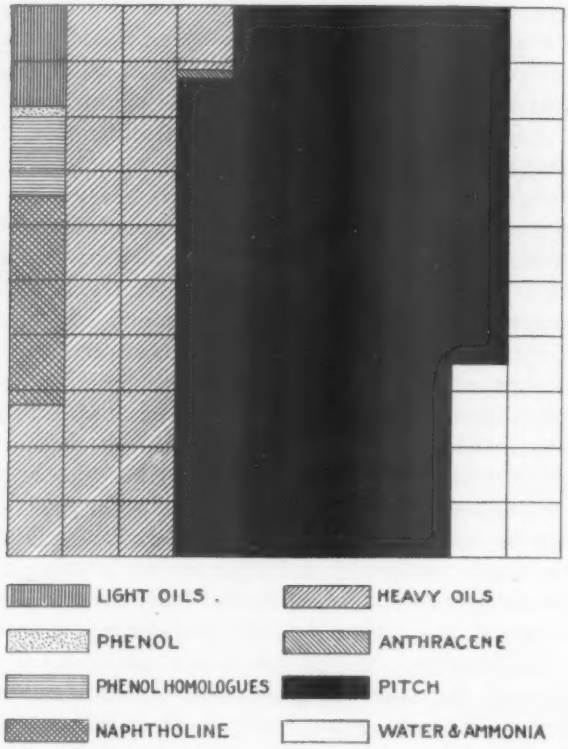


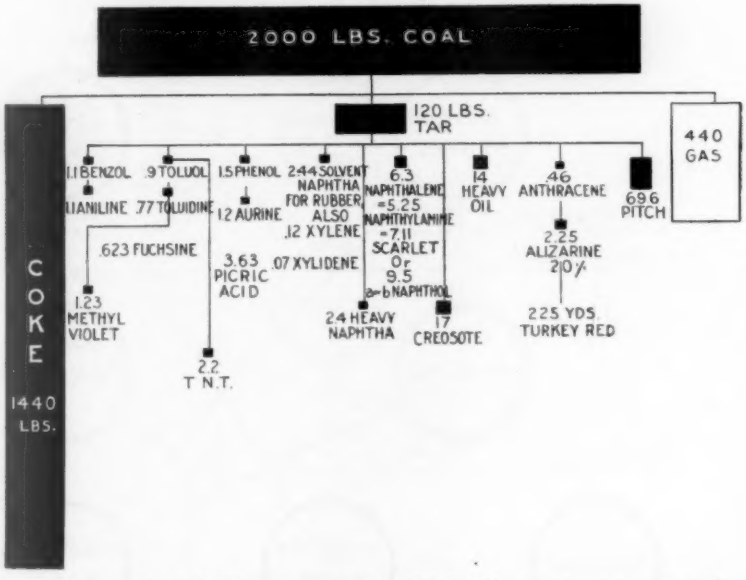
Figure 4 represents the chain of operations necessary for the conversion of the primary raw material—naphthalene—into Naphthol Yellow.

Figure 5 is of particular interest and shows graphically the so-called aniline process for the manufacture of synthetic indigo, from which we see that there are three primary methods having this object in view, all of which, however, aim to produce Phenol-

glycene, which is then subjected by one of three processes, according to patent limitations, into Indoxyl, and this latter product is then, by the oxidizing influence of the air, converted into indigo.

The so-called naphthalene process is shown in Fig. 6. This process has for its object the conversion of naphthalene into indigo and is known as phthalic acid process. The main product obtained is phenylglycine-o-carboxylic acid, which is fused with caustic soda producing indoxyl, and this latter by oxidation is changed into indigo.

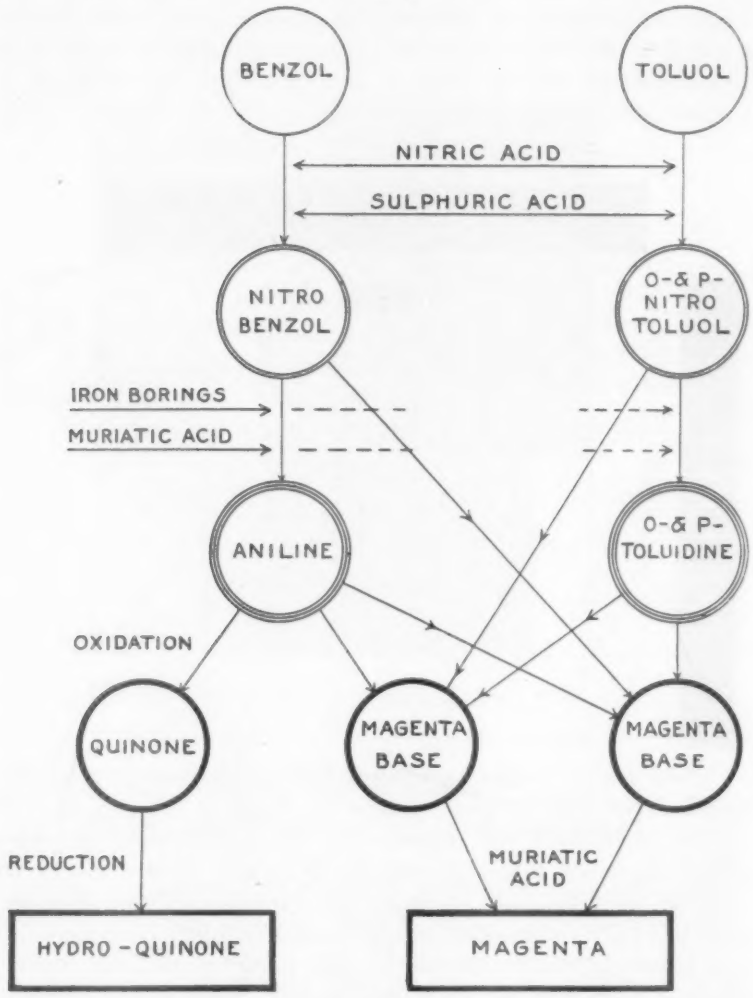
FIG. 2.



These several Indigo processes which I have shown are rather complex, but this complexity need not stand in the way of well-directed students in our organic chemical laboratories for undertaking the work under competent directors. There is not the slightest doubt but that investigating students equipped with personal laboratory manipulating ability and supplied with the necessary patent literature, should be able to carry out, first upon a laboratory and second, on a semi-factory scale, every operation involved in the production of this most important coloring matter, and the practical technical information thereby gained would be of the greatest value for further industrial research.

There were also shown a succession of diagrams illustrating graphically the manufacture of naphthol black, which includes the manufacture of beta naphthol, the conversion of beta naph-

FIG. 3.

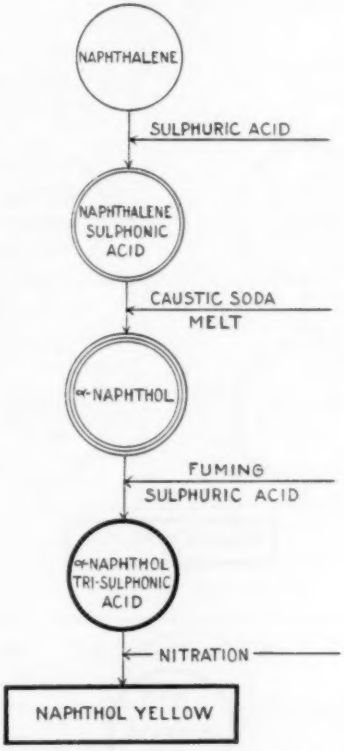


thol into R-salt and G-salt, which are formed simultaneously and separated finally as shown in Fig. 7, and the conversion of the R-salt into the complete dye.

The manufacture of cyanol was illustrated by a succession of slides showing the production of crude benzaldehyde, the conversion of that substance successively into nitro-benzaldehyde, amido-benzaldehyde and oxy-benzaldehyde.

There were also shown illustrations of the process for the production of ortho-nitro-toluol, its conversion into ortho-tolui-

FIG. 4.

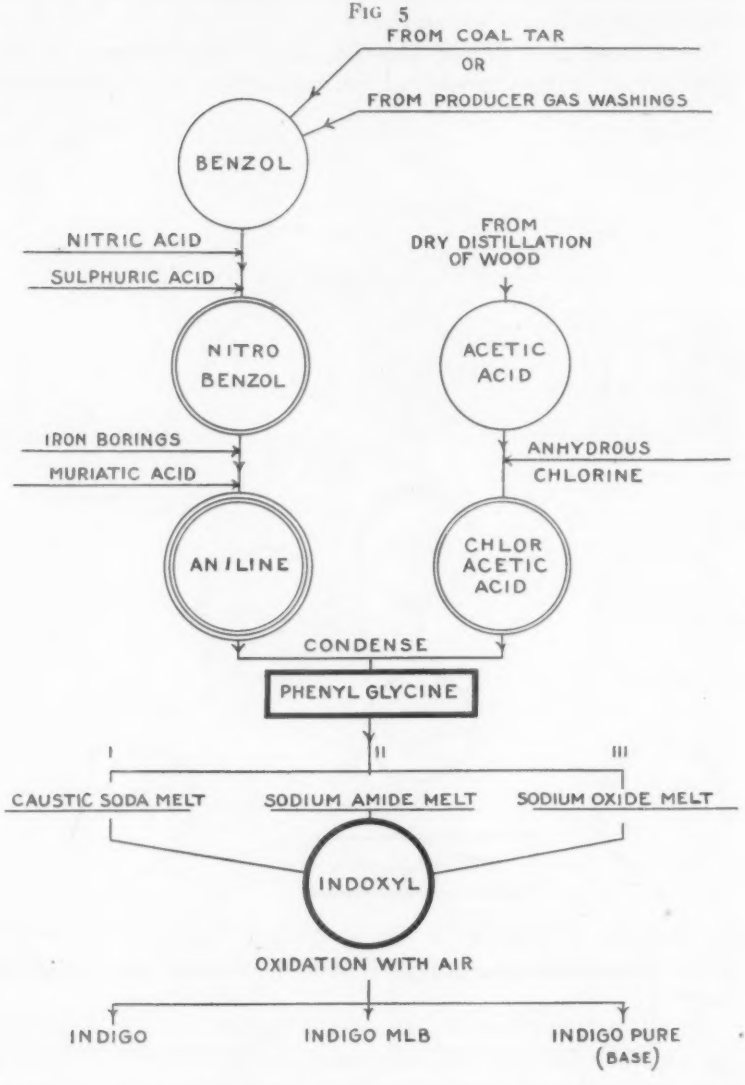


dine and the ethylating of the same, and finally as shown in Fig. 8, the condensing operation and finishing of the completed dyestuff.

From an inspection of the several figures, we are impressed with the fact that dye manufacturing is not entirely chemistry, but is an industry that depends very largely upon the ability of the chemical engineer specially trained in dye making and dye-works equipment. After the preliminary outline of the process

has been worked out, the results of his labor are taken up by others in the plant and gradually brought to manufacturing per-

FIG 5

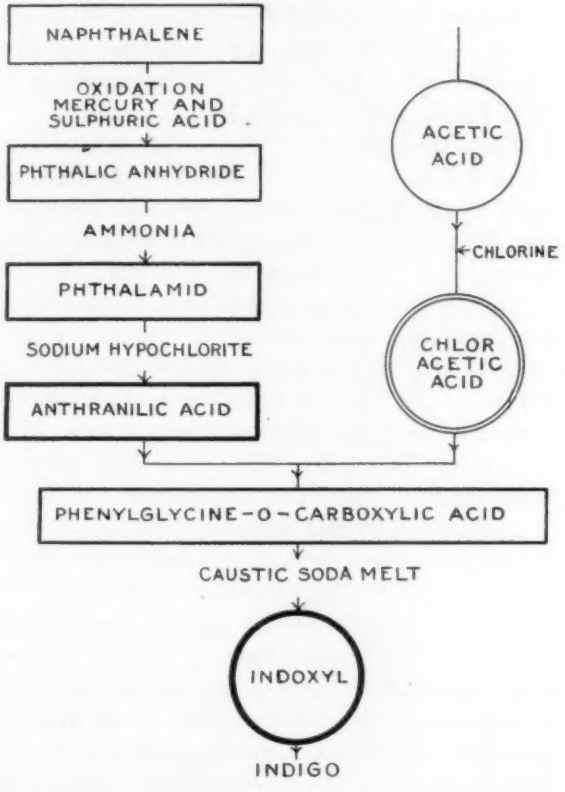


fection, and it depends in a great measure upon the commercial importance of the dye in comparison with dyes known prior to

this discovery. If it possesses properties of fastness not assured by the older dyes, its field of usefulness is thereby enhanced.

In the ordinary course of dye manufacturing as carried out in the large color works abroad or in the more important dye manufacturing plants in this country, the work is divided about as follows:

FIG. 6.



First, *Research Chemists.*—These are men with university training. As a rule they enter the dye works under rather humble conditions until they "find" themselves. Generally they specialize in one and sometimes in two groups of colors and it is seldom that they depart from the confines of their chosen specialty. It is they who experiment and work out what may ultimately appear

on the market as a new dye. Their compensation is rather low; lower than men holding corresponding degrees from American universities. Their ambition is to make discoveries that will yield them royalties on account of their discoveries being good sellers. When a man has made a few discoveries and his dyes are on the market his income in the form of salary and royalties gradually increases and he becomes more or less a fixture in the research department. Ample evidence of this is to be found by carefully inspecting the names of patentees of dyes during the last three years, when we find that the same name occurs at various intervals, and, except in a few instances, is connected always with the same firm.

Second, *Factory Chemists.*—These men are also university graduates, but for one reason or another are less adapted to research work, or do not care for the restraint incident to chemical research. It is they who take up the work where the research chemists leave off. They adapt the chemical discoveries and reactions to factory conditions, and in most instances are the dye production supervisors; they are not foremen. Some of them may have under them two or three departments, for which they are responsible. As a rule it is from the ranks of these chemists that the superintendents or technical directors are obtained.

Third, *Chemical Engineers.*—Owing to their particular training and abilities, these men are responsible for the particular design and installation of the necessary machinery required for manufacturing the various dyes as the results are obtained from both the research chemists and the factory chemists. As a general rule, after the identity of the dye has been proven by the research chemist and after the factory chemist has worked out satisfactorily the sequence of the several operations necessary, even to the production of batches of fifty to one hundred pounds, or even more, and the dye has been demonstrated to be a promising one, it is then that the chemical engineer steps in and designs the plant for its commercial production upon a full factory scale.

Fourth, *The Engineers.*—The engineer department of a dye manufacturing plant goes beyond the corps of chemical engineers, although in some instances these departments may over lead. The engineers, of necessity, are more familiar with the construction of the individual units comprising the plant than the chemical

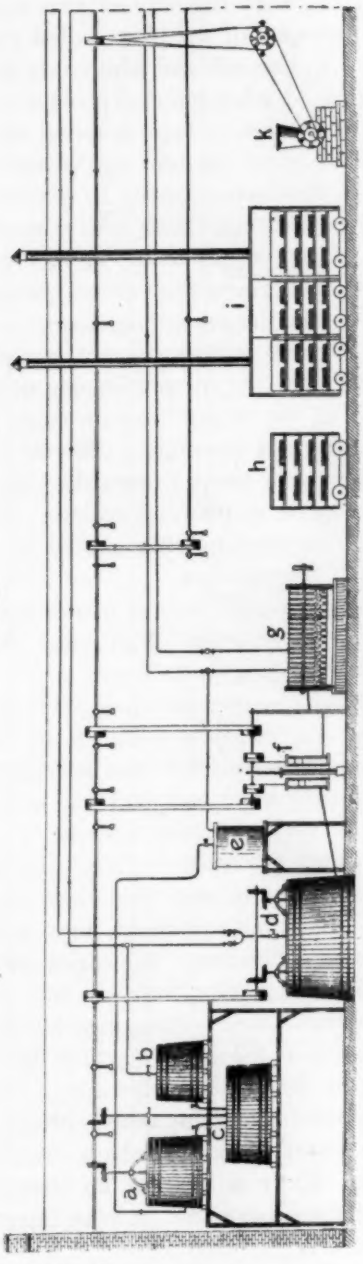


FIG. 7.

NAPHTHOL BLACK MANUFACTURE.

a, Vat for diazotizing the b-naphthylaminedisulpho acid; *b*, vat for dissolving the a-naphthylamine; *c*, vat for producing the amidoazonaphthalinedisulpho acid, and for diazotizing the same; *d*, vat for combining the diazoazo body with R salt; *e*, vat for producing R salt solution; *f*, duplex pump; *g*, filter press for the finished naphthol black B.; *h*, truck for the moist dye; *i*, drier; *k*, grinding mill.

engineers. It is the engineer department that takes care of the construction of the elements of the plant called for by the chemical engineer and factory chemist and whose advice and assistance is at all times encouraged when necessity requires.

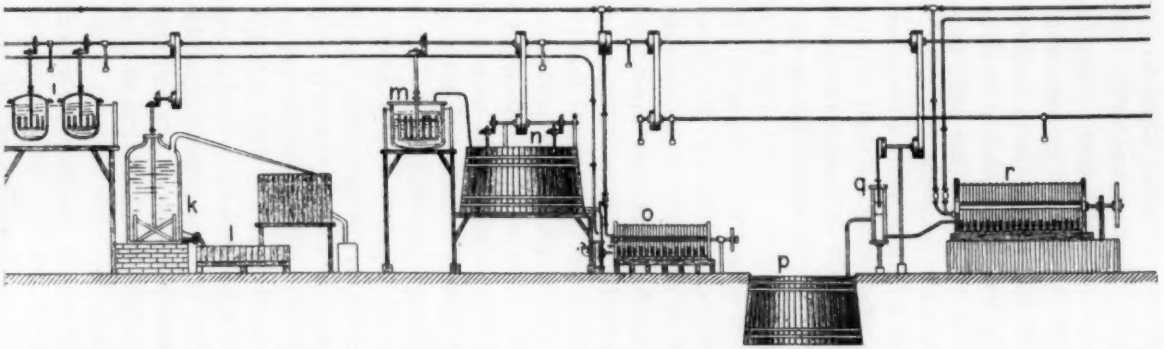
One thing is to be constantly kept in mind, however, regarding the so-called efficiency of German dye plants and that is the utmost care taken by the management to prevent undue intercourse and familiarity between those who comprise the several main departments. There seems to be, in fact there is, a sharp line of demarcation which keeps the various professional groups sharply separated. Unlike the prevailing custom in well-managed American plants, there are seldom, if any, general conferences that have to do with increasing the proficiency of the various departments. In most of the larger German color works there is rather a dense atmosphere of association difficult to penetrate and the existence of which only tends to retard rather than advance the particularly high degree of professionalism. This may be contrary to many pre-conceived notions gained by the American public, but it is a fact, nevertheless.

In dye establishments, distributing plants and similar commercial enterprises, the technical staff may be conveniently divided into two broad groups as follows:

(1) *Textile Chemists,* who specialize more or less in wool, cotton, silk, union goods, etc.—In some of the larger establishments men to fill these positions have been selected from the ranks of the salesmen who may have had previous mill experience, or from graduates of the various textile schools.

(2) *Dye Laboratory Chemists.*—These are usually boys or young men who entertain the idea that they are chemists, but whose preliminary education combined with lack of chemical training, enables them to discharge the duties only of dyer on a miniature scale and consequently they become standardizers or simply shade matchers. These young men become very expert in compounding the dyes of the firm for which they worked and in matching the colors of the firm's competitors. Generally it may be regarded as a mistake for a young man with chemical ambition to lose himself in a standardizing or shade-matching laboratory of a dyestuff house. There is little or no chemical work to be performed, and any knowledge that he may have upon this sub-

FIG. 8.



i, Kettles for condensing oxybenzaldehyde with mono-ethyl-o-toluidine; *k*, still for recovery of unconverted ethyltoluidin; *l*, filter for the condensation product; *m*, sulphonation kettle; *n*, vat for diluting and oxidizing the sulphonation; *o*, filter press for lead sulphate; *p*, neutralizing, and salting-out the dyestuff; *q*, filter press for the finished dyestuff (cyanol).

ject will certainly become stale, since no opportunity is afforded for him to exercise his chemical skill. Except in very few instances have such men ever become valuable technical men in the broad sense of the word, that is, men who are competent to go out into the dye houses of the firm's customers and solve difficult problems in the practical application of dyes or to seek the cause of the trouble, when, through one fault or another, the dyestuffs failed to do their work properly.

It is here that I believe many of our textile schools make the mistake of not suggesting to their dyeing students that they should take up the study of dyeing along some one restricted line and specialize in that. For example, wool. It is manifestly impossible for a man who is a wool dyer to be at the same time a skilled cotton dyer or a skilled silk dyer. I mention these points in order to direct your attention to the circumstances surrounding the employment of chemists in the dyestuff industry. It is an industry that offers remarkable opportunity for experimental work for young men to take up this particular field, but in order to do it to their own satisfaction and that of their employer, it is necessary that they should give serious consideration to the labors required of them and the amount of knowledge necessary for them to discharge their duties satisfactorily.

I have made mention of the employment of chemical engineers in the dye-manufacturing plants, but the satisfactory employment of a chemical engineer in the above organic chemical industry resolves itself again into some special branch of chemical work that the engineer has particularly studied.

Broadly, the color industry is divided into the production of: Raw materials, intermediates, dye making. Any one of these sub-divisions is likely to include one or more of the following operations, each of which is generally complex and which should have the undivided attention of the engineer.

I refer particularly to alkali fusions which are generally preliminary operations.

Sulphonation, which involves the use of either artificial or fuming acids.

Nitration and Liming.—These are operations in which sulphonations are generally decomposed.

Filtration.—Where solids are separated from liquids or *vice*

versa. This is an art. It seems simple at first glance to have a solution with insoluble matter suspended in it or a sludge of greater or lesser density requiring filtration, but it is at its best a problem requiring a great deal of thought, time and attention to be able to successfully filter a given liquid from a solid or a solid from a liquid. There are so many conditions of density, that only long experience can point the way successfully.

It is to be regretted that more young men in our chemical engineering courses have not devoted more time and attention to this particular branch of chemical engineering. Little has been published upon it and the information that has been gained by those who have worked upon filtering problems is generally not divulged.

Drying is another chemical engineering subject that is of the utmost importance, since it occurs so frequently in many phases of dye making, from raw materials to finished dyes. I may mention particularly the production of certain of the Amidonaphthol sulphonic acids and disulphonic acids where both the filtering and the drying determine almost exclusively the value of the finished product. Some of those products depend more upon the skill of the engineer than upon the skill of the chemist.

I could name in succession a number of other important operations, all of which contribute to the successful production of the finished article, and each of which requires that the man in charge—the directing genius—if I may use that term, should be equipped and trained to take care of that particular phase of the work.

Referring again to the amidonaphthol sulphonic acids, I may mention that with the exception of one plant—and that one located in France—no single chemist has been able to successfully carry out every single operation from the conversion of the naphthalene in the first instance to the grinding and sieving of the finished product. This may appear to be a strong statement, but if we consider that to produce these finished products almost every operation previously referred to is involved, it is safe to say that no one industrial chemist or chemical engineer is sufficiently familiar with the innermost details to permit him to successfully direct the work upon every stage in the chain of processes.

Bullet Versus Armor. E. C. CROSSMAN. (*Scientific American*, vol. 118, No. 22, p. 498, June 1, 1918.)—Special armor-piercing bullets were not new when war broke out, but the occasion for them had been limited to getting through the shields of field artillery, and infantry didn't often get close enough to field guns to make this need an urgent one. But after the first year of the war, when snipers began to ensconce themselves behind armor shields and armored cars began to reinforce infantry at threatened points of the line, while airplanes demonstrated surprising immunity to machine-gun fire, the ordnance experts began to take a keener interest in bullets that would not be so easily discouraged on meeting a stubborn steel plate. The most successful armor-piercing bullet yet evolved in this country is that designed by Capt. W. L. Clay of our Ordnance Department, and made at Lowell, Mass., under the supervision of Captain Doe, formerly of our army. This bullet (patent number 1202162), in common with most armor-piercing bullets, uses the hardened steel core within a lead and cupro-nickel outer coating. It differs from any other bullet in that it is closed at the rear and filled from the front end of the jacket, giving higher penetration because of the lessened stripping tendency of jacket and lead. Also it has a softer nose than the tough cupro-nickel jacket. This enables it to bite on hardened steel surfaces very much inclined to its path instead of merely glancing off, as does the service bullet with its sharp nose and long shoulder.

The accuracy of the Clay bullet, while slightly below that of the service bullet, is higher than that of the regular French model, and ample for war use. At 200 yards it makes groups of about eight inches for ten shots, and at 1000 yards it develops some 10 per cent. of fliers, but not enough inaccuracy in the remainder to make its shooting inferior to the regular ammunition from a practical standpoint. The penetration at the muzzle is ¼ to ⅜ inch hardened steel, on which the service bullet merely spattered; at 400 yards it got through ¼ inch, though this was possibly not quite up to Government quality. The trials demonstrated that the making of steel for this light armor, is in itself an uncertain operation. One piece, ¼ inch thick and glass hard, shattered to bits under the bullet's blow. On such steel as this the service bullet does not even offer to go through, merely putting a wide and very shallow dent in the plate; it gives just a blow, without drilling tendency. This is true even on the light $^1/_5$ inch field-gun armor. At 700 yards a service bullet merely dents a ⅜ inch boiler plate, while a Clay slug goes entirely through.

PHYSICS OF THE AIR.*

BY

W. J. HUMPHREYS.

Professor of Meteorological Physics, United States Weather Bureau.

CHAPTER XIV (*Continued*).

Fig. 109, copied by permission from one of Walter's unpublished negatives, shows the ordinary tracery of a lightning discharge when photographed with a stationary camera. It is only a permanent record of the appearance of the lightning to the unaided eye. Fig 110, however, also copied by Walter's kind permission from one of his unpublished photographs, is a record of the same discharge obtained with a rotating camera. It will be noted that the more nearly vertical discharge occurred but once or was single; that this discharge was quickly followed by a second along the same path to about one-fourth of the way to the earth, where it branched off on a new course; that the second discharge was followed in turn at short but irregular intervals by a whole series of sequent discharges; that most of the discharges appeared as narrow intensely luminous streaks, and that one of the sequent discharges appeared, not to the eye, but on the plate of the rotating camera, as a broad band or ribbon. On close inspection it will be obvious that the plaid-like ribbon effect is due, the warp to irregularities in the more or less continuous discharge, and the woof to roughly end-on and therefore brighter portions of the streak. Another point particularly worthy of attention is the fact that while the first and second discharges have several side branches the following ones remain entire from end to end and are nowhere subdivided.

Fig. 108, taken from a photograph obtained by Mr. Larsen, of Chicago, and kindly lent for use here by the Smithsonian Institution, shows another series of sequent discharges similar to those of Fig. 110, except that in this case there was no ribbon discharge. The time of the whole discharge, as calculated by Mr. Larsen, was 0.315 second. Here, too, side branches occur with the first but only the first discharge. This, however, is not an invariable rule for occasionally, as illustrated by Fig. 111,

* Continued from page 75, vol. 186, July, 1918.

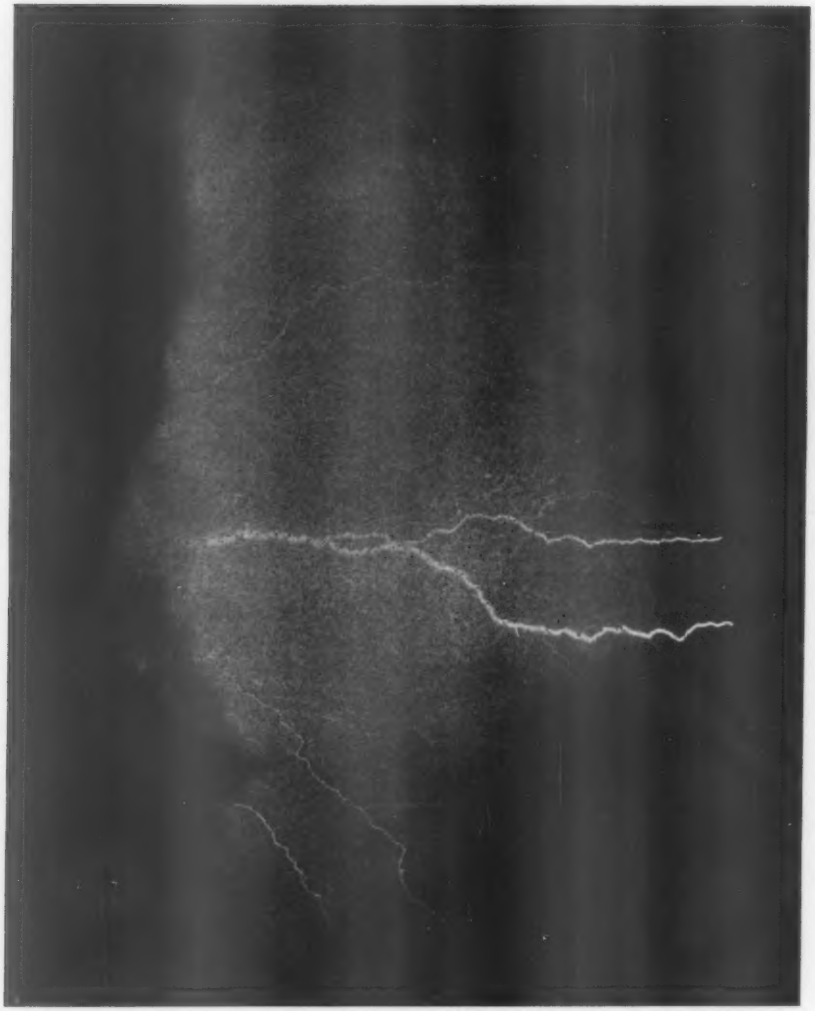
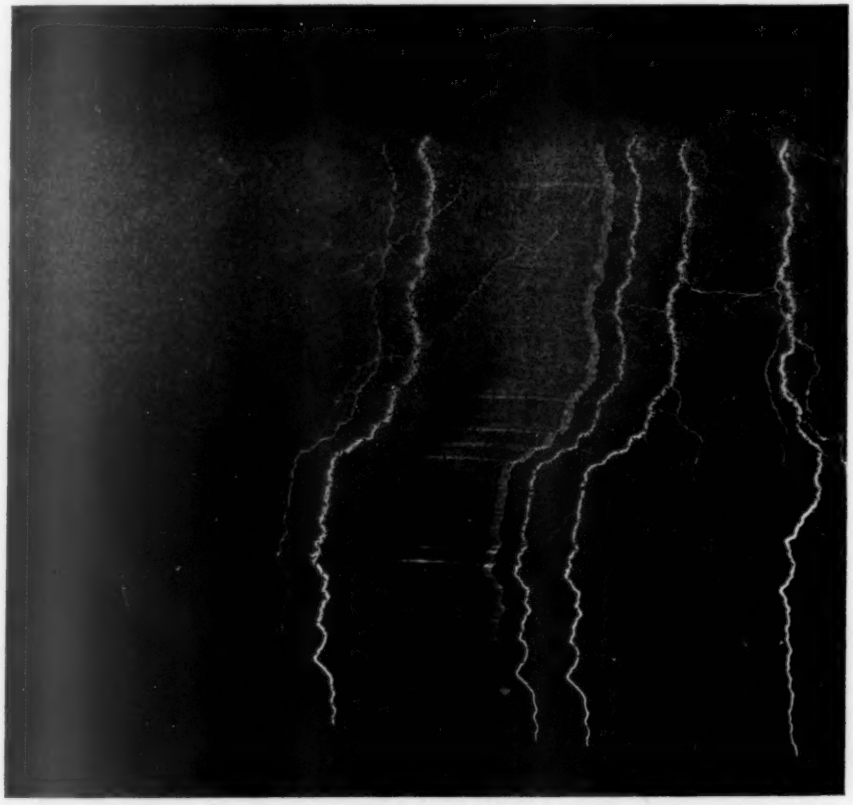


FIG. 109.

Streak lightning, stationary camera; companion to Fig. 110. (Walter.)

copied from a published photograph by Walter, the side branches persist through two or three of the first successive discharges, but not through all. In such case each tributary when repeated follows, as does the main stream, its own original channel.

FIG. 110.



Streak lightning (sequent discharges), rotating camera; companion to Fig. 109. (Walter.)

The phenomenon of sequent discharges, all along the same path, and the disappearance of the side branches with or quickly after the first discharge both seem reasonably clear. The first discharge, however produced, obviously takes place against very great resistance, and therefore under conditions the most favorable for the occurrence of side branches, or ramifications. But the discharge itself leaves the air along its path temporarily highly

ionized, puts a temporary line conductor with here and there a poorer conducting branch, in the atmosphere. This conductor is not only temporary (half the ions are reunited in about 0.15 second, the air being dusty [97]) but also so extremely fragile as to be liable to rupture by the violent disturbances, both explosive and of other types to be discussed later, it itself creates in the atmosphere. Because partly, perhaps, of just such interruptions, and

FIG. 111.

Streak lightning (sequent discharges), rotating camera. (Walter.)

because also of the volume distribution of the electricity which prevents a sudden and complete discharge, the actual discharge is divided into a number of partials that occur sequently. Obviously the breaks in the conducting (ionized) path, if they exist, are only here and there and but little more than sufficient to interrupt the flow. Hence the next discharge, if it occurs quickly, must follow the conducting and, therefore, original discharge path. Besides, in the subsequent discharges the original side branches

[97] Rutherford, *Philosophical Magazine* **44**, p. 430, 1897.

will be quickly abandoned because of their greater resistance, or, what comes to the same thing, because of the more abundant ionization and consequent higher conductivity of the path of heaviest discharge.

This leaves to be explained the genesis of the initial discharge, the least understood perhaps of all the many thunderstorm phenomena. Judging from the voltages required to produce laboratory sparks, roughly 30,000 volts per centimeter, it is not obvious how such tremendous potential differences can be established between clouds or between a cloud and the earth as would seem to be necessary to produce a discharge kilometers in length, as often occurs. Indeed, a fatal objection to the assumption of such high voltage is the effect it would have on the velocity of fall and consequent size of the electrified raindrops. According to Simpson [98], thunderstorm rain often carries as much as 6 electrostatic units of electricity per c.c., and occasionally even more. Hence 30,000 volts per centimeter would produce an electric force on such rain roughly 200 times that due to gravity and therefore either prevent its fall, if directed upward, or, if directed downward, give it a velocity that would quickly break it into fine spray. But thunderstorm rain does not consist essentially of fine spray. On the contrary, as casual observation leads one to believe and as measurements have shown [99], raindrops average larger (1 to 6 mm. in diameter) during a thunderstorm than at any other time. Their velocity of fall therefore can not be excessive, nor indeed does it ever appear to be greatly different from that of ordinary rain. Hence electrical gradients of the order above assumed do not exist between clouds and the earth.

Obviously the potential of individual drops may grow in either of two ways: (*a*) by the union of similarly charged smaller drops into larger ones. In this case, since capacity is directly proportioned to the radius, and the charge, after coalescence, to the volume (if droplets had equal size and charges), the potentials of the resultant drops, that is, their charges divided by their capacities, must be proportional to the squares of their radii, and therefore rapidly increase with coalescence and growth of size; (*b*) by evaporation of however charged drops. Here the charges remain constant and therefore the potential of each individual

[98] *Loc. cit.*, pp. 149–150.

[99] Bentley, *Monthly Weather Review*, **32**, p. 453, 1904.

drop, being inversely proportional to its radius, obviously must become larger as the drop itself evaporates and gets smaller. In each case the tendency of the separate drops to discharge is increased, and the general ionization perhaps somewhat correspondingly increased, but the potential difference between the earth and the cloud as a whole unchanged. At present, therefore, one can do but little more than speculate on the subject of the primary lightning discharge, but even that much may be worth while since it helps one to remember the facts.

As already explained the electrical separation within a thunderstorm cloud is such as to place a heavily charged positive layer (lower portion of the cloud) between the earth and a much higher, also heavily charged, negative layer (upper portion of the cloud). Hence the discharges, or lightning, from the intermediate or positively charged layer may be to either the negative portion above, in some cases even an entirely different cloud, or the earth below. Further, through the sustaining influence and turbulence of the uprushing air there must be formed at times and places practically continuous sheets and streams of water, of course heavily charged and at high potential, and also layers and streaks of highly ionized air. That is, electrically speaking, heavily charged conducting sheets and rods, whether of coalesced drops or of ionized air, are over and over, so long as the storm lasts, momentarily placed here and there within the positively charged mass of the storm cloud.

Consider, then, what might be expected as the result of this peculiar disposition of charges and conductors, the result, namely, of the existence of a heavily surface-charged vertical conductor in a strongly volume-charged horizontal layer or region above and below which there are steep potential gradients to negatively charged parallel surfaces.

The conductor will be at the same potential throughout, and therefore the maxima of potential gradients normal to it will be at its ends, where, if these gradients are steep enough, and the longer the conductor the steeper the gradients, brush discharges will take place. Assume, then, that a brush discharge does take place and that there is a supply of electricity flowing into the conductor to make good the loss. The brush and the line of its most vigorous ionization, other things being equal, necessarily will be directed along the steepest potential gradient or directly toward

the surface of opposite charge. But this very ionization automatically increases the length of the conductor, for a path of highly ionized air is a conductor, and as the length of the conductor grows so, too, does the steepness of the potential gradient at its forward or terminal end, and as the steepness of this gradient increases the more vigorous the discharge, always assuming an abundant electrical supply. Hence, an electric spark once started within a thunderstorm cloud has a good chance, by making its own conductor as it goes, of geometrically growing into a lightning flash of large dimensions. Of course, when the electrical supply is small the lightning is feeble and soon dissipated.

Whether the discharge actually does burrow its way through the atmosphere in some such manner as that indicated probably would be difficult, though not necessarily impossible, of observation. The gradual lengthening of the streak, if the discharge takes place in this manner, might be detected by photographing it on oppositely directed rapidly moving films. A phenomenon roughly analogous to the burrowing progress suggested[100] can indeed be produced on a photographic plate by bringing in contact with the film, some distance apart, two conducting points attached to the opposite poles of an influence machine. Brush discharges develop about each point, but the glow at the negative pole detaches itself and slowly meanders across the plate toward the positive point. As it goes it continually builds for itself, with the silver of the emulsion, a highly conducting path.

Rocket Lightning.—Many persons have observed what at least seemed to be a progressive growth in the length of a streak of lightning. In some cases[101] this growth or progression has appeared so slow as actually to suggest the flight of a rocket, hence the name.

At first one might well feel disposed to regard the phenomenon in question as illusory, but it has been too definitely described and too frequently observed to justify such summary dismissal. Naturally, in the course of thousands of lightning discharges, many degrees of ionization, availability of electric charge, and slopes of potential gradient are encountered. Ordinarily the growth of the discharge, doubtless, is in a geometric ratio and the progress of its end exceedingly swift, but it seems possible for

[100] Leduc, *Comptes rendus*, Paris, 1899, **129**, 37.
[101] Everett, *Nature*, London, 1903, **68**, 599.

the conditions to be such that the discharge can barely more than sustain itself, in which case the movement of the flash terminal may, possibly, be relatively slow, and the appearance of a rocket therefore roughly imitated.

Ball Lightning.—Curious luminous balls or masses, of which C. de Jans [102] probably has given the fullest account, have time and again been reported among the phenomena observed during a thunderstorm. Most of them appear to have lasted only a second or two and to have been seen at close range, some even passing through a house, but they have also seemed to fall, as would a stone,[103] like a meteor, from the storm cloud, and along the approximate path of both previous and subsequent lightning flashes. Others appeared to start from a cloud and then quickly return, and so on through an endless variety of places and conditions.

Doubtless many reported cases of ball lightning, probably the great majority, are entirely spurious, being either fixed or wandering brush discharges or else nothing other than optical illusions, due, presumably, to persistence of vision. But here, too, as in the case of rocket lightning, the amount and excellence of observational evidence forbid the assumption that all such phenomena are merely subjective. Possibly in some instances, especially those in which it is seen to fall from the clouds, ball lightning may be only extreme cases of rocket lightning, cases in which the discharge for a time just sustains itself. A closely similar idea has been developed in detail by Toepler.[104] It might either disappear wholly and noiselessly, as often reported, or it could, perhaps, suddenly gain in strength and instantly disappear as sometimes observed, with a sharp, abrupt clap of thunder.

To say that all genuine cases of ball lightning, those that are neither brush discharges nor mere optical illusions, are stalled thunderbolts, certainly may sound very strange. But that, indeed, is just what they are, according to the above speculation, a speculation that recognizes no difference in kind between streak, rocket, and ball lightning; only differences in the amounts of ionization, quantities of available electricity and steepness of potential gradients.

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[102] *Ciel et terre*, Bruxelles, 1910, **31**, 499.
[103] Violle, *Comptes rendus*, Paris, 1901, **132**, 1537.
[104] *Annalen d. Physik*, Leipzig, 1900, **22**, 623.

Sheet Lightning.—When a distant thundercloud is observed at night one is quite certain to see in it beautiful illuminations, appearing like great sheets of flame, that usually wander, flicker and glow in exactly the same manner as does streak lightning, often for well-nigh a whole second, and occasionally even longer. In the daytime and in full sunlight the phenomenon when seen at all appears like a sudden sheen that travels and spreads here and there over the surface of the cloud. Certainly in most cases, so far as definitely known in all cases, this is only reflection from the body of the cloud of streak lightning in other and invisible portions. Often a blurred, yellowish steak is seen through the thinner portions of the intervening cloud. Occasionally, too, the cloud is wholly cleared in places where, of course, the discharge is white and dazzling. Conceivably a brush or coronal discharge may take place from the upper surface of a thunderstorm cloud, but one would expect this to be either a faint continuous glow or else a momentary flash coincident with a discharge from the lower portion of the cloud to earth or to some other cloud. But, as already stated, only reflection is definitely known to be the cause of sheet lightning. Coronal effects seem occasionally possible, but that they ever are the cause of the phenomenon in question has never clearly been established and appears very doubtful. It has often been asserted, too, that there is a radical difference between the spectra of streak and sheet lightning, but even this appears never to have been photographically, or otherwise definitely established.

Beaded Lightning.—Many photographs showing streaks of light broken into more or less evenly spaced dashes have been obtained and reported as records of beaded lightning. Without exception, however, these seem certainly to be nothing other than photographs of alternating-current electric lights, taken with the camera in motion. On the other hand, it occasionally happens that a reliable observer reports that he has actually seen a discontinuous or beaded streak of lightning. Thus Professor O. J. Ferguson, of the University of Nebraska (Department of Electric Engineering), says:[105]

"In the spring of 1914 a violent thunderstorm swept over Lincoln at about nine o'clock at night. There were numerous vivid lightning displays. One of these discharges occurring in

[105] JOURNAL OF THE FRANKLIN INSTITUTE, V. 179, p. 253, 1915.

the storm front originated at an elevation of about 45 degrees from my viewpoint and struck almost vertically downward. I was watching the storm from the window of a dark room, and the flash occurred directly in front of me. It was a direct stroke of chain or streak lightning.

"However, in dying away, it took probably a full second to disappear, it broke up seemingly into detached portions, short and numerous. In fact, it gave a bead-like effect, and it would be very easy for one to have retained the latter impression and to have called the stroke bead lightning.

"In explanation of this phenomenon I would suggest that each bead probably represents the 'end-on' view of the irregular portions of the lightning path, and that they remained luminous during the subsequent lesser discharges, while the intermediate sections became non-luminous, because viewed from the side."

The explanation offered by Professor Ferguson and illustrated by Fig. 110 doubtless is entirely correct. Hence beaded or pearl lightning must be accepted as a real though unusual phenomenon, which probably would be more often seen if definitely watched for. Indeed, by close observation, the author has several times had that pleasure.

Return Lightning.—This is commonly referred to as the return shock, and is only that relatively small electrical discharge that takes place here and there from objects on the surface of the earth coincidently with lightning flashes, and as a result of the suddenly changed electrical strain. This discharge is always small in comparison with the main lightning flash, but at times is sufficient to induce explosions, to start fires and even to take life.

Dark Lightning.—When a photographic plate is exposed to a succession of lightning flashes it occasionally happens that one or more of the earlier streak images, on development, exhibits the "Clayden effect"—that is, appears completely reversed—while the others show no such tendency. Obviously, then, on prints from such a negative the reversed streaks must appear as dark lines, and for that reason the lightning flashes that produced them have been called "dark lightning." There is, of course, no such thing as dark lightning, since the only invisible radiation to which the ordinary photographic plate is sensitive is the ultra-violet, which cannot be excited by electric discharges

in the atmosphere without at the same time producing visible radiation. Nevertheless, the photographic phenomenon that gives rise to the name "dark lightning," is real, interesting, and reproducible at will in the laboratory.[106]

Duration.—The duration of the lightning discharge is exceedingly variable, ranging from measured intervals of 0.0002 second,[107] and probably less, for a single flash to even a full second or more for a multiple flash consisting of a series of sequent discharges. On rare occasions a discharge of long duration appears *to the eye* to be steady like a glowing solid. Probably the best measurements of the shorter intervals were made by De Blois [108] with the aid of a high-frequency oscillograph. He found the durations of 38 single peaks, averaging 0.00065 second, to range from 0.0002 second to 0.0016 second. Flashes that last as long as a few tenths or even a few hundredths of a second are almost certainly multiple, consisting of a succession of apparently individual discharges occurring at unequal intervals. Occasionally a practically continuous discharge of varying intensity, but all the time strong enough to produce luminosity, will last a few hundredths of a second.

It must be remembered that the duration of even a single discharge and the length of time to complete the circuit, or ionize a path, from cloud to earth, say, are entirely different things. The latter seems usually (rocket and ball lightning may furnish exceptions) to be of exceedingly short duration, while the former depends upon the supply of electricity and the ohmic resistance directly and upon the potential difference inversely.

Length of Streak.—The total length of a streak of lightning varies greatly. Indeed the brush discharge so gradually merges into the spark and the spark into an unmistakable thunderbolt that it is not possible sharply to distinguish between them, nor, therefore, to set a minimum limit to the length of a lightning path. When the discharge is from cloud to earth the length of the path is seldom more than 2 to 3 kilometers; in the case of low-lying clouds even much less, especially when they envelop a mountain peak.

On the other hand, when the discharge is from cloud to cloud

[106] Wood, *Science*, New York (N.S.), 1899, **10**, 717.
[107] De Blois.
[108] *Loc cit.*

the path generally is far more tortuous and its total length much greater, amounting at times to 10, 15, and even 20 kilometers.

Discharge, Where to Where?—As already explained, lightning discharges may be between cloud and earth, between one part and another of the same cloud, or between cloud and cloud. But since the great amount of electrical separation, without which the lightning could not occur, takes place within the rain cloud, it follows that this is also likely to be the seat of the steepest potential gradients. Hence it would appear that lightning must occur most frequently between the lower and the upper portions of the same cloud, and this is fully supported by observations. The next in frequency, especially in mountainous regions, is the discharge between cloud (lower portion) and earth and the least frequent of all, ordinarily, those that take place between one and another entirely independent or disconnected clouds.

Since the electricity of the thunderstorm obviously is generated within the cumulus cloud and there mechanically separated into upper and lower layers it may not at first be clear how discharges can take place to earth at all. Of course, there will be some lines of force between the earth and each cloud charge, but these must be relatively few so long as the charges are equal and approximately superimposed and the resulting dielectric strain correspondingly feeble. However, as the upper charge is carried higher, and especially as it is drifted away from the lower by the winds into which it projects, the lines of force between cloud and earth become more and more numerous, and the strain progressively greater until suddenly relieved by the lightning's disruptive flash.

It would seem, therefore, that a marked difference between the wind velocities at the upper and lower storm levels would be especially favorable to frequency of cloud-to-earth discharges. Hence one would infer that heat thunderstorms, since they occur only when the general winds are light, are less dangerous—less likely to be accompanied by cloud-to-earth lightning—than those (presumably every other type) in which the wind velocity increases more rapidly with elevation. And from this one would further infer that tropical thunderstorms, since they commonly belong to the heat variety, are less dangerous than storms of equal electrical intensity of middle and higher latitudes, where the other or cross-current varieties prevail.

Unfortunately data are not at hand by which these deductions may be tested statistically. They are, however, in accord with the general impression [109] that thunderstorms are more dangerous in England than in India.

Discharges Direct, not Alternating.—Years ago some one for some reason or other, or for no reason, made the statement that the lightning flash is alternating and of high frequency, like the discharge of a Leyden jar, and forthwith, despite the fact that all evidence is to the contrary, it became a favorite dogma of the textbook, passed on unquestioned from author to author and handed down inviolate from edition to edition. True, there often are a number of successive discharges in a fraction of a second, as shown by photographs taken with a revolving camera, but these not only are along the same path but also in the same direction. This is obvious from the fact that side branches, whose trend with reference to the main trunk gives the direction of discharge, persisting as in Fig. 111, through two or more partial or sequent discharges, always follow the same paths. It is also proved by the direct evidence of the oscillograph.[110] In the case of each separate discharge also the direction seems constant; it may vary in strength, or pulsate, but, apparently, it does not alternate.

There are several reasons for concluding that lightning discharges, both single and multiple, are direct and not alternating, of which the following cover a wide range and probably are the best:

(*a*) Lightning operates telegraph instruments. If the discharge were alternating it would not do so, unless very heavily damped.

(*b*) At times it reverses the polarity of dynamos. This requires either a direct current or an alternating one so damped as to be quasidirect.

(*c*) The oscillograph[111] shows each surge or pulsation, as well as the whole flash, to be unidirectional.

(*d*) The relative values of the ohmic resistance, the self-induction, and the capacity, in the case of a lightning discharge,

[109] Symons, *Metrl. Magazine*, **49**, p. 114 and p. 164, 1914.

[110] De Blois, *loc. cit.*

[111] De Blois, *loc cit.*

appear usually, if not always, to be such as to forbid the possibility of oscillations.

From the equation of a condenser discharge,

$$L\frac{d^2Q}{dt^2}+R\frac{dQ}{dt}+\frac{Q}{C}=0$$

it may be shown[112] that whenever the product of the capacity by the square of the resistance is greater than four times the self-induction, or, in symbols, that whenever

$$CR^2>4L$$

oscillations are impossible. Undoubtedly all these terms vary greatly in the case of lightning discharges, but R, presumably, is always sufficiently large to maintain the above inequality and therefore absolutely to prevent oscillations.

To illustrate with perhaps a typical case, assume a cloud whose undersurface is circular with a radius of 3 kilometers, and whose height above the ground is 1 kilometer, and let there be a discharge from the centre of the cloud base straight to the earth: Find a probable value for the self-induction and capacity, and from these the limiting value of the resistance to prevent oscillations, or the value of R in the equation

$$CR^2=4L.$$

To find L we have the fact that the coefficient of self-induction is numerically equal to twice the energy in the magnetic field per unit current in the circuit, and the further fact that per unit volume this energy is numerically equal to $\mu H^2/8\pi$, in which H is the magnetic force and μ the magnetic permeability of the medium. Let a be the radius of the lightning path and assume the current density in it to be uniform. Let b be the equivalent radius of the cylinder, concentric with the lightning path, along which the return or displacement current flows. In this case, μ being unity, the energy W of the magnetic field per unit current and per centimeter length of the discharge is given by the equation

$$W=\log\frac{b}{a}+\tfrac{1}{4}.$$

Let $b=2$ kilometers and $a=5$ centimeters. . Then $W=\log_e 4\times10^4+\tfrac{1}{4}=11$, approximately. Hence the energy of the mag-

[112] J. J. Thomson, "Elements of Electricity and Magnetism," § Discharge of a Leyden Jar.

netic field per unit current for the whole length, 1 kilometer, of the flash is represented by the equation

$$W10^5 = 11 \times 10^5,$$

and the self-induction $= 22 \times 10^5 = 10^{-4}$ henry.

To find C, assume a uniform field between the cloud and the earth. As a matter of fact, this field is not uniform, and the calculated value of C, based upon the above assumption, is somewhat less than its actual value, but not greatly less. Assuming, then, a uniform field we have

$$C = \frac{a}{4\pi d} = \frac{\pi 9 \times 10^{10}}{4\pi \times 10^5} = 225 \times 10^5 = 25 \times 10^{-5} \text{ farad, about.}$$

Hence, by substitution in the equation

$$CR^2 = 4L,$$

it appears that

$$R = 190 \text{ ohms per kilometer, approximately.}$$

Neither a, the radius of the lightning path, nor b, the equivalent radius of the return current, is accurately known, but from the obviously large amount of suddenly expanded air necessary to produce the atmospheric disturbances incident to thunder it would seem that 1 centimeter would be the minimum value for a. Also, from the size of thunder clouds, it appears that 10 kilometers would be the maximum value for b.

The substitution of these extreme values in the above equation gives

$$R = 200 \text{ ohms per kilometer, roughly.}$$

From the fact that C varies inversely and L directly as the altitude of the cloud it follows that, other things remaining equal, the height of the cloud has no effect on the value of R per unit length.

If the altitude is kept constant and the size of the cloud varied C will increase directly as the area, and L will increase directly as the natural logarithm of the equivalent radius of the cylinder of return current. Assuming the area of the cloud base to be 1 square kilometer, which certainly is far less than the ordinary size, and computing as above it is found that

$$R = 850 \text{ ohms per kilometer, roughly.}$$

Again, assuming the base area to be 1000 square kilometers, an area far in excess of that of the base of an ordinary thunderstorm cloud, the result is

$$R = 35 \text{ ohms per kilometer, roughly.}$$

It would seem, therefore, that a resistance along the lightning path of the order of 200 ohms per kilometer, or 0.002 ohm per centimeter, would suffice, in most cases, absolutely to prevent electrical oscillations between cloud and earth. In reality the total resistance includes, in addition to that upon which the above calculations are based, the resistance in parallel of the numerous feeders or branches within the cloud itself. In other words, the assumption that the resistance of the condenser plates is negligible may not be strictly true in the case of a cloud. Nor is this the only uncertainty, for no one knows what the resistance along the path of even the main discharge actually is; though, judging from the resistance of an oscillatory electric spark,[113] it, presumably, is many times greater than the calculated limiting value; and if so, then lightning flashes, as we have seen, must be unidirectional and not alternating.

Temperature.—What the temperature along the path of a lightning discharge is no one knows, but it obviously is high, since it frequently sets fire to buildings, trees, and many other objects struck. In an ordinary electrical conductor the amount of heat generated in a given time by an electric current is proportional to the product C^2RT, in which C is the strength of the current, R the ohmic resistance, and T the time in question during which C and R are supposed to remain constant. In a spark discharge of the nature of lightning some of the energy produces effects, such as decomposition and ionization, other than mere local heating, but as experiment shows, a great deal of heat is generated, according, so far as we know, to the same laws that obtain for ordinary conductors. Hence extra heavy discharges, like extra large currents, produce excessive heating, and therefore are far more liable than are light ones to set on fire any objects that they may hit.

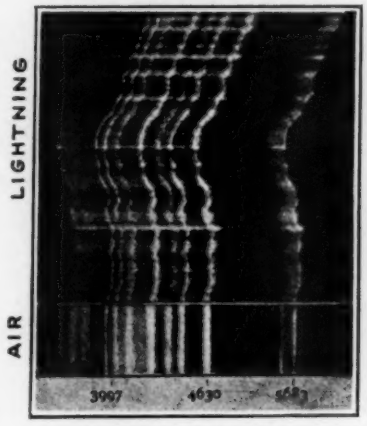
Visibility.—Just how a lightning discharge renders the atmosphere through which it passes luminous is not definitely

[113] Fleming, "The Principles of Electric Wave Telegraphy and Telephony," 2d ed. 1910, 80, p. 228–237.

known. It must and does make the air path very hot, but no one has yet succeeded, by any amount of ordinary heating, in rendering either oxygen or nitrogen luminous. Hence it seems well-nigh certain that the light of lightning flashes owes its origin to something other than high temperature, probably to internal atomic disturbances induced by the swiftly moving electrons of the discharge, and to ionic recombination.

Spectrum.—Lightning flashes are of two colors, white, and pink or rose. The rose-colored flashes, when examined in the spectroscope, show several lines due to hydrogen which, of course,

FIG. 112.



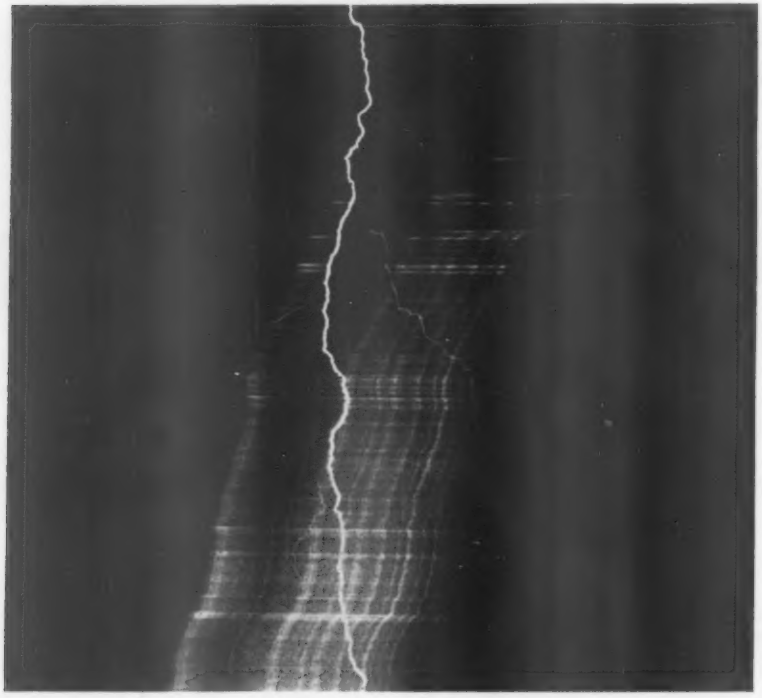
Spectrum of lightning. (Fox.)

is furnished by the decomposition of some of the water along the lightning path. The white flashes, on the other hand, show no hydrogen lines or at most but faint ones. As one might suspect, the spectrum of a lightning flash and that of an ordinary electric spark in air are practically identical. This is well shown by Fig. 112, copied from an article on the spectrum of lightning by Fox,[114] in which the upper or wavy portion is due to the lightning and the lower or straight portion to a laboratory spark in air. Fig. 113 is from an exceptionally fine photograph by Mr. Steadworthy of the Dominion Observatory, Ottawa, Canada. The heavy streak across the spectrum is not the parent, but an accidental stray that got in beside the prism.

[114] *Astrophysical Jr.*, 1913, **18**, p. 293.

It is often asserted that the spectrum of streak lightning consists wholly of bright lines, and that sheet lightning gives only nitrogen bands; and from this it is argued that the latter is not a mere reflection of the first. This assertion is not supported by Figs. 112–113, the brightest portions of which, the portions that

FIG. 113.



Spectrum of lightning; and stray streak. (Steadworthy.)

would the longest be seen as reflection grew steadily feebler, coincide with strong nitrogen bands.

Thunder.—For a long while no one had even a remotely satisfactory idea in regard to the cause of thunder, and it is not a rare thing even yet to hear such a childish explanation as that it is the noise caused by the bumping or rubbing of one cloud against another.

Nor are all the learned explanations wholly free from error. Thus it has been suggested that thunder is due to the mutual

repulsion of electrons along the path of discharge, though there are several objections to this pleasing hypothesis. If such repulsion really occurred to the extent indicated, one might therefore expect a thread or rod of mercury carrying a current to spread out. Instead, however, it actually draws together, and, with a strong enough current, even pinches itself in two. Again, if mutual repulsion actually drove the electrons violently asunder one would expect the discharge instantly to dissipate, producing some kind of a brush effect, instead of concentrating along the familiar streak. Electronic repulsion, therefore, though it must exist to some extent, does not seem adequate, nor, as we shall see presently, is it necessary, to the production of heavy peals of thunder.

Another plausible but erroneous hypothesis in regard to the origin of thunder insists that it is caused by the collapse of the partial vacuum produced by the heat generated by the lightning. Obviously cooling in this case must be rapid, especially at the instant the discharge ceases, but probably not nearly rapid enough to create sound, nor, therefore, ever to produce any of the crashes and rumbling that always follow heavy lightning.

On the other hand, the heating of the atmosphere, the molecular agitation due to ionization, along the discharge path is so great and the resulting expansion so sudden as to simulate a violent explosion and therefore to send out a steep compression wave. Indeed, compression waves generated by electric sparks are so sharply defined that not only they themselves but even their reflections may be clearly photographed.[115] A compression wave, therefore, generated in the manner just explained, apparently is an adequate cause of thunder, and hence, presumably, its only cause.

Rumbling.—Probably the most distinctive characteristic of thunder is its long-continued rumbling and great variation in intensity. Several factors contribute to this peculiarity, among them:

(*a*) Inequalities in the distances from the observer to the various portions of the lightning's path. Hence the sound, which ordinarily travels about 330 meters per second in the air, will not all reach him simultaneously, but continuously over an appreciable interval of time.

[115] Wood, *Philosophical Magazine*, **48**, 218, 1899.

(*b*) Crookedness of path. Because of this condition it often happens that sections of the path here and there are, each through its length, at nearly the same distance from the observer or follow roughly the circumferences of circles of which he is the centre, while other portions are directed more or less radially from him. This would account for, and doubtless in a measure is the correct explanation of, some of the loud booming effects or crashes that accompany thunder.

(*c*) Succession of discharges. When, as often happens, several discharges follow each other in rapid succession there is every opportunity for all sorts of irregular mutual interference and reinforcement of the compression waves or sound impulses they send out. Occasionally they may even give rise to a musical note of short duration.

(*d*) Reflection. Under favorable conditions, especially when the lightning is at a considerable distance, the echo from clouds, hills, and other reflecting objects certainly is effective in accentuating and prolonging the noise and rumble of thunder. But the importance of this factor generally is overestimated, for ordinarily the rumble is substantially the same whether over the ocean, on a prairie, or among the mountains.

Distance Heard.—The distance to which thunder can be heard seldom exceeds 25 kilometers, while ordinarily, perhaps, it is not heard more than half so far. To most persons, familiar with the great distances to which the firing of large cannon is still perceptible, the relatively small distances to which thunder is audible is quite a surprise. It should be remembered, however, that both the origin of the sound and often the air itself as a sound conductor are radically different in the two cases. The firing of cannon or any other surface disturbance is heard farthest when the air is still and when, through temperature inversion or otherwise, it is so stratified as in a measure to conserve the sound energy between horizontal planes. Conversely, sound is heard to the least distance when the atmosphere is irregular in respect to either its temperature or moisture distribution, or both, for these conditions favor the production of internal sound reflections and the dissipation of energy. Now the former or favorable conditions occasionally obtain during the production of ordinary noises, including the firing of cannon, but never during a thunderstorm. In fact, the thunderstorm is especially likely to estab-

lish the second set of the above conditions, or those least favorable to the far carrying of sound.

Then, too, when a cannon, say, is fired the noise all starts from the same place, the energy is concentrated, while in the case of thunder it is stretched out over the entire length of the lightning path. In the first case the energy is confined to a single shell; in the second it is diffused through an extensive volume. It is these differences in the concentration and the conservation of the energy that cause the cannon to be heard much farther than the heaviest thunder, even though the latter almost certainly produces much the greater total atmospheric disturbance.

The Ceraunograph.—Various instruments, based upon the principles of "wireless" receivers and known as ceraunographs, have been devised for recording the occurrence of lightning discharges, whether close by or so far away as to be invisible and their thunder unheard. Of course, the sensitiveness of the instrument, the distance, and the magnitude of the discharge, all are factors that affect the record, but by keeping the sensitiveness constant, or nearly so, it is possible with an instrument of this kind to estimate the approximate distance, progress, and to some extent even the direction and intensity of the storm. Nevertheless, there does not appear to be much demand for this information, and therefore at present the ceraunograph is but sparingly used.

Chemical Effects.—As is well known, oxides of nitrogen and even what might be termed the oxide of oxygen, or ozone, are produced along the path of an electric spark in the laboratory. Therefore, one might expect an abundant formation during a thunderstorm of these same compounds. And this is exactly what does occur, as observation conclusively shows. It seems probable, too, that some ammonia must also be formed in this way, the hydrogen being supplied by the decomposition of raindrops and water vapor.

In the presence of water or water vapor these several compounds undergo important changes or combinations. The nitrogen peroxide (most stable of the oxides of nitrogen) combines with water to produce both nitric and nitrous acids; the ozone with water gives hydrogen peroxide and sets free oxygen; and the ammonia in the main merely dissolves, but probably also to some extent forms caustic ammonia.

Symbolically the reactions seem to be as follows:

$$2NO_2 + H_2O = HNO_3 + HNO_2.$$
$$O_3 + H_2O = H_2O_2 + O_2.$$
$$NH_3 + H_2O = NH_4OH.$$

The ammonia and also both the acids through the production of soluble salts are valuable fertilizers. Hence, wherever the thunderstorm is frequent and severe, especially, therefore, within the tropics, the chemical actions of the lightning may materially add, as has recently been shown,[116] to the fertility of the soil and the growth of crops.

Explosive Effects.—As already explained, the excessive and abrupt heating caused by the lightning current explosively and greatly expands the column of air through which it passes, thereby shattering chimneys, ripping off shingles, and producing many other similar and surprising results. It also explosively vaporizes such volatile objects as it may hit that have not sufficient conductivity to carry it off. Hence trees are stripped by it of their bark or utterly slivered and demolished through the sudden volatilization of sap and other substances; wire fused and vaporized; holes melted through steeple bells and other large pieces of metal, and a thousand other seeming freaks and vagaries wrought.

Many of the effects of lightning appear at first difficult to explain, but, except the physiological, which, indeed, are but little understood, and probably some of the chemical, nearly all depend upon the sudden and intense heating along its path.

[116] Capus, Guillaume, *Annales de géographie*, 1914, **23**, p. 109.

(To be continued.)

A SURFACE HAVING ONLY A SINGLE SIDE.*

BY

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Member of the Institute.

ALL the usual surfaces with which we are familiar have two sides; a sheet or shell having no appreciable thickness is representative of the mathematician's surface; one side could be colored differently from the other; mathematicians recognize this two-sided property when they refer to the two normals at a point of a surface as differing only in their algebraic signs. The surface of a sphere must be considered as a shell, therefore having an outer, convex, or positive side, and an inner, concave, or negative side.

It is quite simple, however, to devise a true surface which has only one side, and as this has some very odd and peculiar properties the following description of it may be of interest; and when this surface is better understood perhaps some applications of it may be found. Steinmetz in the *Journal of the American Chemical Society*, May, 1918, p. 733, for instance, showed how this and the Riemann surface, on account of their peculiar properties, can be used for illustrating some of the complicated relations in the periodic system of the chemical elements.

If the two ends of a strip of paper or of a flat ribbon be brought together to form a ring, and a twist of half a turn be given to it before the ends are secured together, such a single sided surface (and with only a single edge) is produced. But this form of it is geometrically quite complex and irregular, because the paper does not bend edgewise, and it therefore does not lend itself well to an analytical investigation; it is doubtless for this reason that it had apparently not received the attention it deserves. In order to study the peculiarities of this odd form of surface, the writer constructed numerous models of what he considers to be the simplest type of the geometrically most regular form of it; this regular form, it seems, had not been investigated analytically before.

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* Communicated by the Author.

Let *C, C,* Fig. 1, represent a circle shown in perspective. Let a straight line *ab* start from the position 1 in the plane of this circle; let this line be moved as a generatrix along the circle as a directrix and always remain in planes passing through the axis of the circle. Simultaneously with this motion let it revolve around the circle as its axis and at *half* the angular rate of its movement around the circle. Hence, when it has moved 90° around the circle, clockwise, into the position 2, it will be inclined 45°, clockwise, to the plane of the circle; in the position 3 it will be perpendicular to this plane; in the position 4 it will be inclined 135°, and when it arrives at the origin again it will have revolved 180° in its own plane; hence, will coincide with its original position 1, but will be reversed in its direction, as is shown in the nearby dotted position 5.

The surface thus described seems to be the simplest geometrically regular form of this one-sided surface, and as its generation follows a regular law it lends itself to analytical investigation. A carved wooden model of this surface when the generatrix *ab* is of a limited length and much less than the diameter of the circle, is shown in Fig. 2, it being then a ring; it of course also has only a single edge. The white zone in the middle represents the centre-line circle, although distorted somewhat on account of the thickness of the ring required to give it strength.

In Fig. 1, the lines *ab* in positions 2 and 4 are in fact parallel, and they are necessarily so in a model constructed in space, but geometrically the line has in fact revolved 90° around its circular axis in passing from 2 to 4; this will be evident if one imagines oneself moving along with the line and always facing it; hence, for position 4 one is supposed to be looking at it from the rear, or from the reversed side of the paper as though it were transparent. With a solid model, such as Fig. 2, this is readily seen by turning the model in the plane of the circle while following the revolving line. It is, therefore, only apparent and not real that the line does not change its direction in passing from positions 2 to 4 through 3, and that it reverses its direction completely in passing from 4 to 2 through 1.

Geometrically considered the straight line generatrix *ab* is of infinite length, but to study this peculiar surface it is best to first start with that limited portion of it which will form a ring, Fig. 2, which will be the case when the length of the line *ab* (the

width of the ring) is considerably less than twice the diameter of the circular directrix; this line must necessarily extend equally to both sides of the circle, or else no continuous and uniform ring will be formed.

If such a ring were made of a dielectric and completely covered to near the edge with tin foil, it would not act as an electrical condenser. If an ordinary surface be characterized as bipolar because it has two sides which are algebraically or geometrically of an opposite nature, the present surface would need

FIG. 1.

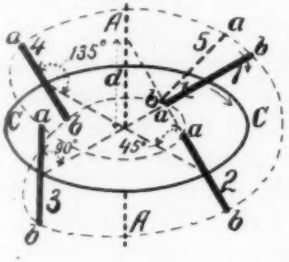

FIG. 3.

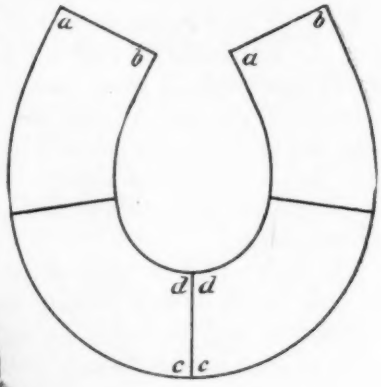

FIG 2.

to be called non-polar. This is its chief peculiar characteristic and places it in an entirely different class of surfaces. For instance, a pin stuck vertically through such a surface would at first seem to represent two normals of opposite sign at the same point; but as the apparently two sides are really one, the pin in fact constitutes two normals at two different points on the *same* side of the surface, which two points coincide in space; relatively to the surface these two normals are like the two outward extensions of a diameter of a spherical shell, and as the two latter may be said to have the same polarity with reference to the shell (if this term may be used as meaning the same direction

relatively to the surface, and from the same side of a surface), then the two normals represented by the pin through this ring also have the same polarity, in which respect they differ radically from the two normals represented by a pin stuck through a spherical shell, the two parts of which would have opposite polarities. The present surface simply has no "other side" and is therefore radically different from the usual ones; if one were to paint one complete side of such a ring one would find that there was no unpainted side left.

If such a ring when made of something flexible, like paper, be cut along the centre-line circle, it will form only one ring of double the diameter.[1] This large ring has then lost the characteristics of this surface, as it has two sides like the usual surfaces; it has four half twists instead of one. Hence, if the present ring, Fig. 2, were covered with tin foil and the foil be cut along the centre-line circle, it would act as a condenser. Or if the ring be colored on the half to only one side of the centre-line circle and then cut as before, it would form a ring which is colored on one side and white on the other. Merely cutting this surface along its centre-line circle, therefore, puts it into the same class as the usual surfaces.

If such a ring be made of paper it could be given any number of half twists before joining the ends. All those in which the number of half twists is an odd one belong to this class; those with an even number belong to the usual class of surfaces. When given three half twists and then cut as before the double-size ring will be found to have a regular knot tied into it. Instead of using a line *ab* as the generatrix it may be a regular polygon, like a triangle, square, etc., and the twists may then be in thirds, quarters, etc.; this, however, leads to solids as distinguished from surfaces.

Mechanically the centre of gravity of such a ring (considered now as having an appreciable thickness) is at its geometric centre; hence, when revolved around its axis it will be perfectly balanced statically. When thus revolved, it forms an excellent model for showing the characteristic motions in a vortex ring. It is statically balanced also around position 1 as an axis.

[1] This and other features of popular interest were described by the writer in an article on "A Flat Band With Only One Surface and One Edge"; in the *Scientific American*, Feb. 21, 1914, page 156.

Cut in two along an axial plane through the original position 1 in Fig. 1, the two halves are identical in shape; also when cut in two by a plane through the original position and perpendicular to the axis. To make such a ring accurately and without internal strains, it is best to start with a tore (a circular ring of circular cross section), mark off on its surface where the edges will be (according to the law explained in connection with Fig. 1), and then cut away the material down to those lines. A fairly close approximation may be made far more simply from paper, cardboard or sheet metal, by cutting it to the horse-shoe shape, as in Fig. 3 (the approximate development of this surface), and bringing the edges together, *a* to *a* and *b* to *b*. There are, of course, two possible directions of the twist, a right and a left. The ring may also be conceived to be formed of a straight helix (like the usual twist drill) with a half twist, and then bent around to make its axis a circle.

Such rings are only limited portions of this surface in the form of zones. In order to obtain an idea of this surface when extended to infinity the writer made the wire model shown in different positions in Figs. 4, 5, 6 and 7. Beyond the limits of these wires, to infinity, there is nothing of interest, as all the geometric contortions which this surface must go through in order to have only one side are within and near the circular directrix. The sixteen regularly spaced straight wires are all of the same length and are bisected by the circular directrix; the solid ring is merely to hold them in position. In all of them the four chief or cardinal positions of the straight line generatrix are numbered as in Fig. 1; *A* is the axis.

Fig. 4 is nearly in line with the original position 1, and shows the tangential axis *A*. Fig. 5 is about a quarter turn from the former and is nearly in line with the plane of the position 2; it shows the parallelism of positions 2 and 4, and with the intersection *S*. Fig. 6 is about a half turn from position 1 and therefore nearly in line with position 3; it shows the intersecting line *S*. Fig. 7 is approximately from the top, and shows chiefly the edges of the zones of various widths.

The three cords stretched between the wires show the shapes of limited portions or zones like the ring in Fig. 2, extending equal distances to both sides of the circle. The width of the outer zone *O* is nearly four times the diameter of the circular

directrix; it shows the general shape of the surface as it passes out to infinity after having gone through its contortions. It will be seen from the top view, Fig. 7, that the edge makes three turns of 360° in completing its circuit; it intersects the axis twice and the intersection S four times. The width of the next smaller band $2D$ is twice the diameter of the circle; hence, it

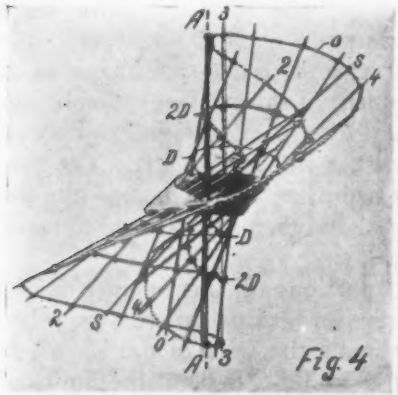

Fig. 4

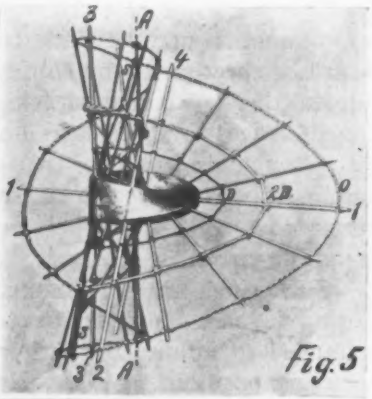

Fig. 5

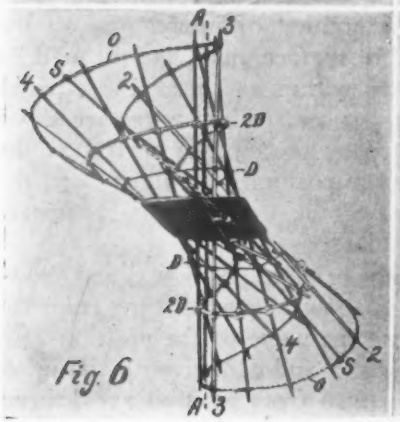

Fig. 6

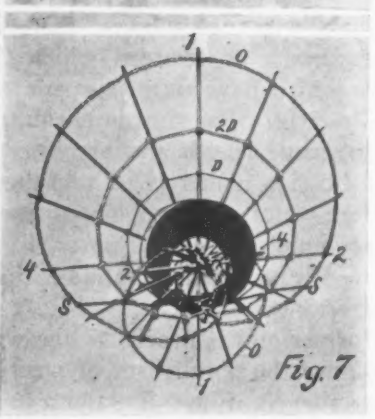

Fig. 7

intersects that circle; its edge again makes three turns to complete its circuit and also intersects the axis twice; it intersects the intersection S only twice and is tangent to it once.

The width of the next one, D, is equal to the diameter of the circle; hence, it meets the axis only once and at this point the axis is tangent to the edge of the ring; it intersects the intersec-

tion S twice; this and all smaller ones make only two turns of 360° to complete their circuits, the third loop now having contracted into the point of tangency with the axis. In this one the part of the surface which is near the axis is for a short distance practically in an axial plane, and it is the only ring in which this is the case. Mechanically this one is of interest as it can be secured at this tangential edge to a shaft for revolving it, hence without the spokes required for the smaller ones.

Rings of less width than the diameter of the circle are all like the solid ring in the model, that is, like Fig. 2, whose width is a little less than half the diameter; as in the case of ring D, their edges make only two turns in the complete circuit; they do not intersect the axis at all, but intersect the intersection S twice. The limiting ring is, of course, the circular directrix itself.

The axis A is throughout its whole length tangent to the surface, as every position of the generatrix, of course, intersects it. This is of interest in that it shows that this much-curved surface has a second straight line element besides the generatrix. This feature enables this surface to be defined algebraically as one generated by a right line, ab, Fig. 1, intersecting the axis, A, at different angles and revolving around it so that the axial distance, d (shown for position 2), from the normal position 1 is always equal to the tangent of half the angle, e, of revolution of its plane from that of the normal position 1; and the angle it makes with the axis is always the complement of the angle $\frac{1}{2}e$. This way of defining it eliminates the circular directrix and shows it to be related to helical surfaces.

This surface must necessarily intersect itself when its width (measured in the axial planes) is greater than twice the diameter of the circle. A curious feature is that the self-intersection of this much-curved surface seems on the model to be a straight line, S, making an angle of 45° with the plane of the circle, and lying in a plane tangent to it and perpendicular to the original position 1 of the generatrix. Hence, this surface contains three parallel lines, positions 2, 4, and this intersection S; the latter is equally distant from the other two, and the two planes through it and each of the other two are at right angles to each other.

As every position of the right line generatrix must intersect this line of intersection S and also the axis, it follows that this surface may also be defined as one generated by a right line

generatrix always intersecting two other non-intersecting right line directrixes, each of which makes an angle of 45° with the plane of the other and the normal between them; and that it advances along these lines at certain different trigonometric rates. This also eliminates the circular directrix and shows the surface to be related to warped surfaces. There appear to be no other right lines on this surface than those described.

If it is true that the self intersection S is a straight line, then it follows that this surface can also be defined as one generated by a right line which is moved so as to always be in contact with two other right lines and a circle, one of which lines is the axis

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

of the circle and the other is inclined 45° to the plane of the circle and lying in a plane tangential to the circle. This way of defining it eliminates all angles and trigonometric functions.

Another odd feature is that the unlimited surface has two trumpet-shaped, clear, passages through it which are completely separated from each other, such that one liquid might be passed through one of them and another through the other without mixing. This might at first appear inconsistent with the statement made above concerning the condenser action, as these two liquids could now act as the two poles of a condenser. From the model, however, it is readily seen that the formation of these two passages is due to the fact that the surface intersects itself.

The principal cross sections of this surface are shown in Figs. 8 to 13, in all of which R is the radius of the circle, A the axis, and S the line of self-intersection; the right lines, of course, extend to infinity in both directions. Fig. 8 is in the plane of the circle; this seems to be the only section in which there is a perfect circle. Fig. 9 is in the axial plane through the original position 1. Fig. 10 is in the plane of the two 45° positions 2 and 4, Fig. 1. Fig. 11 is in the axial plane half way between those of Figs. 9 and 10. Fig. 12 is in a plane through the line of intersection S and the orginal position 1, and Fig. 13 through this same line S and either of the two 45° positions 2 and 4, Fig. 1; the normal distance between these parallel lines is equal to $R\sqrt{1.500}$. The sections parallel to the plane of the circle are, of course, all curved loops, each intersecting itself and then passing off to infinity in nearly opposite directions, but they seem to be of no particular interest. The shapes of the edges of the various rings or zones projected on the plane of the circle are seen in the top view, Fig. 7.

When referred to three coördinates, one parallel to the axis, the other parallel to the position 1, and the third perpendicular to both of the others, then the surface is cut three times by every coördinate except the axis itself, which is a tangent throughout, and position 1, which lies entirely on the surface.

In discussing this surface with N. W. Akimoff he evolved the following equation for it, just before going to press:

$$x\left(x^2+y^2-r^2\right)+ryz=\pm\left[yz-(x^2+y^2-r^2)\right]\sqrt{x^2+y^2}$$

In this the geometric centre of the surface is at the origin of the coördinates, and the circle whose radius is r, is in the plane of x and y; hence, the axis A in the figures is the axis Z; position 1 lies in the positive direction of x.

Making $x=-r$ gives in the first place y numerically equal to z, which indicates that the self-intersection S is the 45° right line described above; and as another solution $y=0$, which indicates the straight line 3.

Plentiful Supply of Building Stone and Brick Clays. ANON. (U. S. Geological Survey, *Press Bulletin*, No. 358, March, 1918.)—The large quantities of high-grade granite and valuable brick clays near Richmond, Va., are especially noted in Bulletin 483, published by the United States Geological Survey, Department of the Interior, under the title, "Economic Geology of Richmond, Virginia, and Vicinity." The massive granite that comes to the surface over a large area in the western part of Richmond, says N. H. Darton, the author of the report, is in greater part well suited for use as building stone of the highest grade, and the supply is well-nigh inexhaustible. In recent years Virginia has ranked among the first ten of the granite-producing states, and, though the demand for all building materials has been slackened by the war, the demand for granite and other natural stone will no doubt revive when the country is once more at peace.

The loamy clays in this region are well adapted to use in making building brick, and as they occur in extensive deposits they form the basis of a large industry, Henrico County being the leading one of Virginia in the manufacture of common brick. In 1917 over 43,000,000 brick, valued at $304,000, were made in this county, a considerable increase over the output for 1916.

Mr. Darton found considerable deposits of diatomaceous earth about Richmond, which have so far not been utilized. This earth is used chiefly for cleaning and polishing, either in the form of powder or mixed with soap. It is an effective nonconductor of heat and has been used alone or with other materials as a covering for boilers, steam pipes, and safes and in fireproof cements. It is used largely by paint manufacturers as a wood filler. Boiled with shellac it is made into records for talking machines. It has been used for absorbing liquid manures so that they could be utilized as fertilizers and as a source of silica in making water glass, as well as in the manufacture of cement, tile glazing, artificial stone, ultramarine and other pigments of aniline and alizarine colors, paper filling, sealing wax, fireworks, hard-rubber objects, matches, and papier-maché, and for solidifying bromine.

Teachers of economic and other branches of geology will find this report especially valuable, both for its text and for its numerous clear-cut and instructive illustrations. Bulletin 483 will be sent free on application to the Director of the United States Geological Survey, Washington, D. C.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

DETERMINATION OF PERMEABILITY OF BALLOON FABRICS.*

By Junius David Edwards.

THE BUREAU has published a description of the various methods which may be employed for determining the permeability of balloon fabrics to hydrogen. The precise and rapid method used at the Bureau of Standards measures the hydrogen penetrating a given area of fabric by means of a gas interferometer. Data are given to show the effect upon the apparent permeability of different experimental conditions such as temperature, pressure, humidity of the gas, etc. A knowledge of the effect of these factors enables one to compare results of tests made under different conditions. The test adopted as standard by the Bureau is described.

THE STANDARDIZATION OF THE SAYBOLT UNIVERSAL VISCOSIMETER.[1]

By W. H. Herschel.

[ABSTRACT.]

THE Saybolt Universal viscosimeter has always been at a disadvantage, as compared with the Engler instrument, because it has never been standardized with respect to its principal dimensions. To overcome this difficulty the Bureau of Standards entered into negotiations with Mr. George M. Saybolt, and he agreed to accept certain instruments as standard. In some preliminary work with other instruments, it was found that the relation between absolute viscosity and the time of flow could be expressed by the equation.

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00213\,t - 1.535/t \qquad \text{Eq. 1}$$

* Communicated by the Director.

[1] Technologic Paper No. 112.

where t is the time of flow in seconds, and absolute viscosity and density are expressed in *cgs* units. A similar equation, obtained by using the standard instruments furnished by Mr. Saybolt, was

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00220\,t - 1.80/t \qquad \text{Eq. 3.}$$

Equations of this sort may be used in various ways. If the viscosity and density are known for suitable calibrating liquids, the times of flow, for viscosimeters of normal dimensions, may be calculated from Eq. 2. By comparing these times of flow, with the times obtained by experiment, it may be determined whether or not the instruments at hand are of normal dimensions. These equations also serve as a ready means for finding the time ratio of two different types of viscosimeter. For example, the equation previously found for the Engler instrument No. 2204 U was

$$\frac{\text{Absolute viscosity}}{\text{Density}} = .00147\,t - 3.74/t \qquad \text{Eq. 3}$$

By comparing Eqs. 2 and 3 it may be found that when the last terms of the equations are negligible, as they are when the time of flow is greater than about 400 seconds, the time will be 1.50 times as long for a flow of 200 cubic centimeters from the Engler instrument, as for 60 cubic centimeters from the Saybolt instrument. This time ratio increases as the value of t decreases, and for a time, Saybolt, of 36.5 seconds, the time ratio is 1.70.

Results obtained with the Engler viscosimeter are usually reported in Engler degrees, though such results do not, as sometimes supposed, represent relative viscosities. Values in Engler degrees are obtained by the purely arbitrary rule of dividing the time for the liquid tested, by the time for distilled water at 20°C (68 F). The time for water may vary from 50 to 52 seconds, so this value should be used in connection with Eq. 3.

All liquids of known viscosity are not equally suitable for determining the equation of short tube viscosimeters of the usual types. These instruments discharge into the air so that the retarding effect, due to surface tension, is different in different liquids. As these instruments are used mainly for oils, the equations should be found by means of liquids having approximately the same surface tension as oil. Considering the

available liquids from this viewpoint, glycerol and sucrose solutions have too high a surface tension, and ethyl alcohol solutions are to be preferred on this account. The surface tension of water is also too high, but water would be excluded on other grounds, even if it were possible to reduce its surface tension without materially changing its viscosity. The viscosity of water is so low that the flow is turbulent, resulting in a change in the constants of formulas like Eqs. 1, 2 and 3.

It has previously been impossible to determine whether a Saybolt Universal Viscosimeter gave normal readings, as neither the dimensions, nor normal times of flow for any given liquids were known. Now that these data have been determined, limit gages have been prepared, and the Bureau of Standards is now in a position to certify whether or nor a given instrument is of standard dimensions.

GROUND CONNECTIONS FOR ELECTRICAL SYSTEMS.*

By Orville S. Peters.

An investigation of methods of grounding to protect persons from dangers associated with electrical circuits has recently been completed by the Bureau of Standards. The results are to be published in more extended form in a Technologic Paper. The investigation was undertaken in view of the fact that some of the methods of grounding now in use have in many cases proved unsatisfactory, and also that the information heretofore available on the subject is scattered through technical journals and reports and is consequently more or less inaccessible to those most interested in it.

Dangers to persons from electrical systems arise because of the occasional entrance of abnormally high voltage upon the low voltage parts of electrical circuits and equipment, to which persons have access, through faults in insulation between high-voltage and low-voltage circuits. Such faults are developed for the most part by lightning and breakage of wires in storms, and occasionally by high voltage singes or deteriorated insulation.

The magnitude of the potential differences which may appear between low-voltage circuits or parts of equipment and ground is governed by a number of factors, but chiefly by the voltage of the line with which contact is made and the relative location of the

*Technologic Paper No. 108.

point of failure. For instance, with a 2200-volt a.c. distribution circuit feeding a low-voltage lighting circuit through a step-down transformer, a failure of insulation at an end turn of the high voltage winding may raise the potential difference between the lighting circuit and ground to a value approaching 2200 volts unless provision is made with a view to preventing it. A similar condition may arise with any low-voltage circuit if it makes contact with a high-voltage circuit.

Danger from high potentials between low-voltage circuits or parts of equipment and ground can best be averted by grounding the parts affected. For a high degree of safety to life the resistance of the ground connection should be such that with a current flow equal to the rated current of the nearest circuit breaker which will operate to disconnect the equipment or circuit concerned from the source of the dangerous voltage in the event of an accident to insulation, the potential difference between grounded wire and ground will not exceed 150 volts, if the grounded wire, or parts of equipment connected with it, is accessible. If the latter are inaccessible a higher voltage limit is permissible.

Water pipes offer by far the most desirable means of making ground connections, but where it is necessary to resort to other means, such as driven pipes or plates, an appreciable degree of protection can in some places be obtained at reasonable expense. In a great many cases, however, grounds of the latter type will be found unsatisfactory. If a common ground wire is used, a good degree of protection can be had, but the expense may be considerable, and the result not equal to that obtainable from water pipes, unless the common ground wire is connected to a water pipe.

The resistance of water pipe ground connections, where there are no high resistance joints nearby, averages about 0.25 ohm, which is sufficiently low for practical purposes in any case that is likely to arise. The resistance of driven pipe and plate grounds, however, is much higher than that of water pipe grounds. A series of measurements on ground connections made with driven pipes, plates, coils of wire and patented devices showed results as given in the accompanying table. These ground connections were found in service in a number of cities located in different parts of the United States between the Atlantic Coast and the Rocky Mountains.

RESISTANCE BY KINDS OF SOIL.

Number of grounds tested	Soil	Average Resist.	Minimum Resist.	Maximum Resist.
24	Fills, and ground containing more or less refuse, such as ashes, cinders, and brine waste.	14	3.5	41
205	Clay, shale, adobe, gumbo, loam, and slightly sandy loam with no stones or gravel.	24	2.0	98
237	Clay, adobe, gumbo, and loam mixed with varying proportions of sand, gravel and stones.	93	6	800
72	Gravel, sand and stones with little or no clay or loam.	554	35	2700

From these measurements it is readily seen that except in certain localities where natural conditions are particularly favorable towards making ground connections with driven pipes or plates, to obtain a degree of safety equal to that obtained with water pipes would entail an expense that would be almost prohibitive. It is possible, of course, to obtain an appreciable degree of protection with driven pipes in nearly all places, but the comparative advantages in connecting to water pipes are so great that the latter should be used wherever they are available.

Municipalities and water companies are urged to permit the connection of electrical circuits to their water pipes, especially from the point of view of safety to the public. There is, moreover, no possibility of damage to the pipes from currents flowing in them, nor of danger to employees of the pipe owning company, if simple precautions are observed in regard to the use of the pipes for the purpose of grounding.

TESTS OF LARGE BRIDGE COLUMNS.*

By J. H. Griffith and J. G. Bragg.

[ABSTRACT.]

Nature of Investigation.—Tests were made upon eighteen large bridge columns which were half size models of chord sections of railroad bridges recently erected at St. Louis, Mo., Metropolis,

*Technologic Paper No 101.

Ill., and Memphis, Tenn. The specimens were constructed of nickel, mayari, chrome, silicon and high carbon steels. They varied in length from 15½ feet to 24½ feet, and in cross sectional areas from 42 to 119 sq. in. The slenderness ratios varied from 15 to 44. The columns were of modern design and were constructed in accordance with approved methods of shop practice.

It was the purpose of the investigation to determine the strength of the members as affected by the particular designs and grades of steel used, also the laws of distribution of stress and strain throughout the shafts and details.

Methods of Tests.—The columns were tested in the 10,000,000-lb Olsen compression machine of the Bureau at Pittsburgh. Extensometers of eighty inch gauge length were placed at each corner of the shafts symmetrically with respect to the mid points of the numbers. These were used for the purpose of obtaining data to determine how each column behaved as a unit when subject to stress. Portable Berry gauges of eight and sixteen inch gauge lengths were used to determine the behavior of the details, a large number of observations being made at each 5000 lbs. per sq. in. increments of load.

The data was subsequently used as the basis of determinations of the relative strength of the members, their proportional limits, moduli, deflections and other elastic coefficients. A comparative discussion was given of the data. The laws of behavior were discussed with reference to the designs, types of steel used, independent physical tests of the steels, and compared with similar tests of other investigators.

Results of Observations and Tests.—The strengths of the columns varied from a minimum of 31,200 lbs. per square inch for the carbon steel to a maximum of 65,700 lbs. per square inch for the mayari steel members, the intermediate values corresponding to the grades of steel used in the construction of the columns. The strength for twelve columns failing as units were approximately defined by the yield points of the individual steels used in the construction, being confined within a zone determined by the upper and lower limits obtained by independent tests of the component steels. The mean deviation was found to be one half per cent. from the mean yield points determined for the columns

at failure, the range of variation being from 4 to 12 per cent. Of the remaining six columns four failed by local bending at the ends and two by body failures due apparently to the unsymmetrical action of lattice bars.

The mean modulus of elasticity of the columns was found to be 29,000,000 ± 120,000 lbs. per square inch, or approximately that of the component steels. The coefficient of lateral expansion was .30 or approximately that found for steel. The proportional limit of the stress-strain curves of the members was approximately only half that which is found for plain steel. It is believed this reduction was influenced by initial strains from riveting and the built up character of the members.

There was evidence of some lack of integrity of action of the component steel shapes. This was attributed to variations in yield points, a probable breaking down of the frictional resistance between shapes, and the influence of initial strain in the steel from fabrication processes.

The tests to determine the behavior of details showed that there was relative slipping of pin plates at comparatively low loads due to the intensity of the stress just over the pins. It was shown that the lattice without intermediate transverse bars behaved to some extent as a pantograph linkage superposed on the shafts, this causing larger stress in the lattice at the points of constraint near battens and transverse diaphragms than occurred in bodies of the columns. The presence of transverse bars in the Metropolis Bridge columns, it was believed tended to cause a more uniform distribution of stress in the lattice stress. The evidence to support this opinion was found in the fact that the columns having the additional transverse bars always failed in smooth deflection curves, the curves being more or less irregular in those with diagonal lattice alone.

A full discussion was given of the effects of intial eccentricity, the laws of stress distribution from bending of columns, and the laws of distributions in pin plates and lattice. The analyses were conducted from the point of view of the column formula used in design and the more rational formula based on initial eccentricity in a column.

SOME CHARACTERISTICS OF THE MARVIN PYRHELIOMETER.[1]

By Paul D. Foote.

[ABSTRACT.]

THE behavior of the Marvin Pyrheliometer has been investigated in detail. The instrument was calibrated by two methods, one in which a known amount of electrical energy was dissipated in the receiver, and the other in which a known amount of radiation from a black body was allowed to fall upon the receiver in the same manner as when the pyrheliometer is employed for solar measurements. The calibration by the two methods agreed within the limits of experimental error. The various constants of the instrument were determined and it was found that the fundamental constant relating the amount of energy received with the rise in temperature of the receiver is independent of the rate of energy supply, at least for an electrical calibration. This fact could not be determined with certainty for a radiometric calibration, because the amount of energy which can be suppled radiometrically from a black body is very small compared to the energy of the solar radiation. The Marvin pyrheliometer calibrated as above was compared by solar observations with the U. S. Weather Bureau Smithsonian standardized pyrheliometer S. J. No. 1, which had been calibrated by comparison with the Smithsonian primary standard water flow pyrheliometer. The Marvin instrument gave 2 per cent. lower values than the Smithsonian pyrheliometer. This difference is within the errors of observation in the calibration of the Marvin Pyrheliometer by the methods employed above.

Jan. 23, 1918.

INSTRUMENTS AND METHODS OF RADIOMETRY III. THE PHOTOELECTRIC CELL AND OTHER SELECTIVE RADIOMETERS.[2]

By W. W. Coblentz.

DURING the past ten years investigations have been in progress in this Bureau to determine the characteristics, the comparative sensitivity and the applicability of various types of instruments for measuring radiant energy.

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[1] Scientific Paper No. 323.

[2] Scientific Paper No. 319.

The present paper deals with the application of special physical and chemical properties of matter, as a means of quantitatively measuring radiant energy.

Certain substances have the property of decreasing in electrical resistance when exposed to radiant energy of short wave-lengths; especially the visible and ultra-violet rays. Crystalline selenium belongs to this class of substances, and because of its very marked response to light, its application as a radiometer has been thoroughly investigated by many observers. The sensitivity of the selenium cell varies not only with the wave-length but also with the intensity of the light stimulus; and it recovers but slowly from the effects of the light stimulus. It therefore fails to meet the requirements of a radiometer, except that of high sensitivity.

The application of the photo-chemical action upon a photographic plate, as a means of making quantitative radiometric measurements is considered. While this method of radiometry has been used successfully, its applications seem to be rather limited.

A third application of radiometry, considered in this paper is based upon the fact that some substances, when charged to a negative potential, lose their charge when exposed to light; especially violet and ultra-violet rays. The alkali metals and especially their hydrides, are very sensitive to light stimuli. The photoelectric cells made of these substances can be constructed and operated so that the response (photoelectric current released) is proportional to the intensity of the stimulus. This meets one of the principal requirements of a satisfactory radiometer. Details of construction, operation, and characteristics of the photoelectric cell are given.

A satisfactory, high-resistance, iron-clad Thomson galvanometer is described, which may be used successfully with the photoelectric cell. The advantages of the photoelectric cell over the thermopile are considered and the application of the former is advocated for measurements of radiant energy (especially ratios of intensities) in the violet and ultra-violet parts of the spectrum, where the photoelectric cell greatly exceeds the thermopile and the bolometer in sensitivity.

WASHINGTON, Sept. 10, 1917.

COPPER.[1]

A COMPILATION has been published by the Bureau of the most accurate published information concerning the physical and mechanical properties of the metal copper, together with data and discussion on the effect of higher and lower temperatures upon the physical properties as well as that of impurities in the metal. The circular is concluded with a comprehensive bibliography of the subject, and some typical standard specifications for the metal in different forms.

This circular is one of a series dealing with properties of metals and alloys.

SCOPE AND APPLICATION OF THE NATIONAL ELECTRICAL SAFETY CODE.[2]

[ABSTRACT.]

THE National Electrical Safety Code consists of four parts and a supplementary section on grounding. The present publication gives a summary of the different parts and points out the need for these safety rules and their present status. This need is illustrated by the citation of one hundred accidents which have occurred from electrical causes.

The method which was used in preparing the Code is described and the reasons given for the form and specific contents of the Code. Instructions are given for finding rules which would apply to any particular installation or situation and the method for making an inspection based upon the Code rules is outlined.

The rules were developed through the coöperation of many engineering and utility associations, engineers, state and municipal officials, electrical workers and others interested in the subject. The rules have already been adopted in certain states and are under consideration in others. Meanwhile they are being tried on a tentative basis by many utility corporations and others to whom they would apply. Manufacturers are greatly modifying their designs so as to conform to the Code rules and all interests are coöperating to secure one standard of electrical construction, installation and operation throughout the country.

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[1] Circular No. 73.
[2] Circular No. 72.

THE FRANKLIN INSTITUTE.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

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Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
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Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	
Clark, Walton, Jr., Capt.	Field Artillery	
Coates, Jesse, Major	American Expeditionary Force	France
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R. I.

Name and rank	Branch of service	Location
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J. Major.	War plans division, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Private	437th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
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Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France

Name and rank	Branch of service	Location
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major		Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington

Name	Appointment	Location
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
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Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lenher, Victor, Major	Chemical Service Section, N. A.	Washington
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration .	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.

Name	Appointment	Location
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member of Council of National Defense	Philadelphia
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Wadleigh, Francis R,	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

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MAJOR WILLIAM J. HAMMER, in care Inventions Section, War Plans Division, General Staff, War College, Washington, D. C.

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MR. H. CLYDE SNOOK, in care Wilson H. Snook, Savage Building, Paulding, Ohio.

NECROLOGY.

Mr. Warner Walter, 1233 Market Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

ALVORD, J. W., and BURDICK, C. B.—Relief from Floods; The Fundamentals of Flood Prevention. 1918.

COLVIN, F. H.—Aircraft Mechanics Handbook. 1918.

CREHORE, A. C.—The Mystery of Matter and Energy. 1917.

CUNYNGHAME, H. H.—Time and Clocks. 1906.

FLINT, W. R.—Chemistry for Photographers. 1916.

FRYER, P. J., and WESTON, F. E.—Technical Handbook of Oils, Fats and Waxes, vol. 1. 1917.

GOLDSMITH, A. N.—Radio Telephony. 1918.

HILDEBRAND, J. H.—Principles of Chemistry. 1918.

Mineral Industry.—Vol. 25. 1916.

PEELE, ROBERT, ed.—Mining Engineers' Handbook, 1918.

Photograms of the Year.—Annual Review. 1917–18.

PRIDEAUX, E. B. R.—Theory and Use of Indicators. 1917.

BOOK NOTICES.

THE CHEMISTRY OF FOOD AND NUTRITION. By Henry C. Sherman, Ph.D. New York, The Macmillan Company, 1918. Second edition, rewritten and enlarged, 431 pages, contents and index, illustrations, tables, 12mo. Price, $2.

Dr. Sherman's extended and valuable contributions to our knowledge of food chemistry guarantee that this work will be an acceptable addition to the literature of that subject, and careful reading confirms this. The book contains a large amount of information, clearly and accurately expressed. It is not written as a popular essay, for the statements are mostly presented in the elaborate form and technical language of the well-developed science.

A large amount of statistical information is given in the form of tables. After presenting the general chemistry and nutritive relations of the three main types of food a chapter is devoted to enzymes and digestive processes, then follow detailed discussions of the problems of metabolism and energy requirements. The value of inorganic substances, especially iron compounds, in the diet is considered, after which over one hundred pages are devoted to practical applications of the principles set forth in the earlier part of the work. An appendix on the nomenclature and classification of proteins and one on the composition of foods close the book.

No mention is made of the dietetic relations of the accessory foods. It would have been interesting to hear Dr. Sherman's summary of the existing trustworthy data concerning the effects of alcohol, tea, coffee and cacao, but in a work of this kind the author usually finds it necessary to exclude certain incidental topics.

Notwithstanding the great amount of information in the work, the excellent style in which it is written and the care that has been taken to be

accurate and thorough, the reviewer feels that many a thinking reader will close the book with a puzzled feeling. Can the human dietary be reduced to a mere question of calories? One is reminded of the story of the little girl, who, having been fed for a week or so on artificial foods, suddenly sat up in bed and said: "Not another ounce of nourishment will I take. I want my dinner." There are psychic elements in our food-taking that cannot be ignored. It is not, however the duty of the chemist to discuss these, but in the field of food-control and dietetic regulation, the old proverb that one man's meat is another man's poison must not be forgotten. The United States have never had a national food-problem until the present, and it is very important that the scientific data and the psychologic features should be given thorough consideration. Dr. Sherman's book will be a valuable addition to the former phase.

HENRY LEFFMANN.

JAMES WOODHOUSE: A PIONEER IN CHEMISTRY, 1770–1809. By Edgar F. Smith, Provost of the University of Pennsylvania. Philadelphia, The John C. Winston Company, 1918, 299 pages, plates, portrait, 12mo. Price, $1.50.

If it were not for the chapter devoted to his scientific work in Provost Smith's former volume entitled "Chemistry in America," the name of James Woodhouse would scarcely be familiar to the chemists of the present generation. It is nevertheless true, however, that this almost-forgotten Philadelphian was one of the great pioneers of chemistry in America, and one of the bright stars among the galaxy of worthies that made our city the centre of American science a century ago.

In this biography the author presents us with an intimate account of the life and personality of Dr. Woodhouse, as well as a most interesting and appreciative discussion of his scientific efforts and achievements.

The life of this remarkable man of science was singularly free from dramatic incidents, and the main facts of it can be recited very briefly. His parents had come to Philadelphia from England in 1766, and it was in this city that he was born in 1770. And it was in his native city also that he received his elementary education and his scientific training and that he spent practically the whole of his career. He died as Professor of Chemistry and Dean of the Medical School of the University of Pennsylvania in 1809.

His interest and love for the science to which he was to devote his life were awakened in him while he was an undergraduate student in the University, and it was the personality and fame of Doctor Benjamin Rush that attracted him to the Medical School after he had taken the degree of Bachelor of Arts. Before completing his medical course he briefly served as surgeon in the army during an Indian campaign, but he promptly resumed his studies and passed his examinations for the degree of Doctor of Medicine after presenting a rather elaborate thesis on a chemical subject.

After a brief medical career he decided to devote himself to the pursuit of chemistry. To promote chemical research and to disseminate the latest and most valuable information on chemical subjects he founded the Chemical Society of Philadelphia, the first chemical society in the world, of

which he was the first and the only president. In this capacity he succeeded in enlisting the coöperation of a large circle of specialists, and in giving much useful instruction and advice to his fellow citizens.

In 1795 he was elected Professor of Chemistry in the Medical School of the University, the Professorship having been declined by Joseph Priestley. The chair had previously been occupied by James Hutchison.

In 1796 Woodhouse was elected a member of the American Philosophical Society, in the affairs of which he was active until his death, serving at various times as secretary and councillor.

By far the most important contributions Woodhouse made to chemical science were between 1795 and 1809, *i.e.*, the period during which he occupied the chair of chemistry in the University. In spite of his limited preparation and equipment he rapidly forged ahead to become the acknowledged leader in his chosen field. Without question his greatest achievement was that he succeeded in establishing both by experiment and by his writings correct ideas on the fundamental processes of chemistry, such as combustion, respiration, the formation and decomposition of water, etc. He combated the erroneous views of Priestley (whom he greatly admired as a discoverer), and of other exponents of the phlogistic theory, and championed the teachings of Lavoisier and the French school.

As an investigator he made many valuable observations and discoveries in vegetable chemistry, and succeeded, independently of Davy and Gay Lussac, in isolating potassium. He also devised numerous methods of chemical analysis which although crude and imperfect compared with those of the present day, have proved of great service in his hands and those of his contemporaries.

Woodhouse was a great believer in the laboratory method of instruction. His biographer is evidently of the opinion that he was one of the first chemists either here or abroad to emphasize the value of direct experimentation, and he calls attention to the fact that "The Young Chemists Pocket Companion," published in 1797, was "in all probability the first published guide in experimentation for chemical students."

No less important than his work as an investigator and teacher were his unremitting and successful efforts to develop and improve industrial chemical processes, and to make the natural resources of his country available for the well-being and prosperity of the inhabitants of the newly born republic.

He was beloved and admired by his students, to not a few of whom he succeeded in imparting his own enthusiasm for research and teaching. And one of these at least—the illustrious Robert Hare—even surpassed his master in these respects.

Such are a few of the outlines and high lights in the picture which Provost Smith has painted for us in the Life of James Woodhouse. To enjoy and appreciate the perspective and warmth of color, as well as the wealth of detail, a careful perusal of this little volume is necessary. It constitutes a most acceptable contribution to our knowledge of the first beginnings in our country of the great science which now counts its votaries by

tens of thousands, and which has grown to be an indispensable aid to the nation in both peace and war.

HARRY F. KELLER.

ORGANIC COMPOUNDS OF ARSENIC AND ANTIMONY. By Gilbert T. Morgan. London, Longmans, Green & Co., 1918, 350 pages, contents, introduction, bibliography and index, illustrations, 8vo. Price, $4.80 net.

This work is one of a series of monographs on Industrial Chemistry, each of which is to be under the charge of a specialist, the whole to be editorially supervised by Sir Edward Thorpe, C.B., LL.D., F.R.S. Twenty-eight are enumerated as already planned, of which several, including the present volume, have been issued. It is interesting to note that four volumes are assigned to synthetic colors.

The work under review contains a very large amount of matter, carefully and plainly set forth, and really will astonish the average chemist by the array of organic derivatives that have been produced by the standard synthetic methods. Of course, when such compounds are mentioned, every chemist thinks of the kakodyl derivatives, and one of the most interesting portions of the book is the historical note concerning these, starting with an account of the first preparation of the impure kakodyl oxid, which was long known under the title of "Cadet's Fuming Liquor." The exact nature of the principal constituent of this liquid was ascertained by Bunsen, in a series of researches which Berzelius said, justly, would alone give a name that would live as long as the science of chemistry. It is also generally known to chemists that Bunsen discovered the remarkable fact that while so many of the kakodyl derivatives are highly poisonous, kakodylic acid is a striking exception.

The interest that attaches to the substances described in this work arises from two sources: the antiquity of the earliest production of them, and their powerful and special physiologic effects. Louis Claude Cadet de Gassicourt, a military apothecary, residing in Paris, published in 1760 an account of the experiments which produced the "fuming liquor," the composition of which long remained undetermined. The physiologic effects of arsenical organic derivatives have of late been prominently before the world in connection with "salvarsan" or, as first termed, "606," so much now in favor as an antisyphilitic remedy.

Dr. Morgan's book is a most valuable addition to the chemistry of this important field of synthetic work. It is well-printed and provided with a good index and an extended bibliography. The reviewer is glad to note that the spelling "gram" is used.

HENRY LEFFMANN.

HELVETICA CHIMICA ACTA: Under this title the Swiss Chemical Society has begun the publication of the papers presented to it. The first number, just at hand, is of the ordinary octavo size, with 96 pages of printed matter. The numbers will be issued about every two months. The papers will appear mostly in one of the three languages spoken in Switzerland: French,

Italian and German. Among the contributions to the first number may be noted the following that are interesting either by novelty or practical application: Guye and Schneider (in French), "Reduction of Nitrogen Oxides to Ammonia"; Gassmann (in German), "On the Occurrence of Hydrogen Selenid in Rain and Snow"; Pictet and Sarasin (in French) "On the Distillation of Cellulose and Starch under Reduced Pressure."

All of the contributions are of a high scientific character.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Chemistry of Food and Nutrition, by Henry C. Sherman, Ph.D. Second edition, rewritten and enlarged. 454 pages, illustrations, 12mo. New York, The Macmillan Company, 1918. Price, $2.

Organic Compounds of Arsenic and Antimony, by Gilbert T. Morgan, D.Sc. 376 pages, 8vo. London, Longmans, Green & Co., 1918. Price, $4.80.

Edible Oils and Fats, by C. Ainsworth Mitchell, B.A. 159 pages, illustrations, 8vo. London, Longmans, Green & Co., 1918. Price, $2.

University of Illinois, Bulletin: Water Survey Series, No. 14. Chemical and biological survey of the waters of Illinois. Report for the year ending December 31, 1916. Edward Barton, Director. 190 pages, illustrations, 8vo. Urbana, University, 1917.

U. S. Bureau of Standards: Circular No. 73, Copper. 103 pages, illustrations, plates, 8vo. Scientific Paper, No. 321. Thermal expansion of alpha and of beta brass between 0 and 600° C. in relation to the mechanical properties of heterogeneous brasses of the Muntz metal type, by P. D. Merica and L. W. Schad, associate physicists. 19 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

U. S. Bureau of Mines: Bulletin 132, Siliceous Dust in Relation to Pulmonary Disease Among Miners in the Joplin District, Missouri, by Edwin Higgins, A. J. Lanza, F. B. Laney, and George S. Rice. 110 pages, illustrations, plates, 8vo. Bulletin 151, Recovery of Gasoline from Natural Gas by Compression and Refrigeration, by W. P. Dykema. 123 pages, illustrations, plates, 8vo. Bulletin 164, Abstracts of Current Decisions on Mines and Mining Reported from September to December, 1917, by J. W. Thompson. 147 pages, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States, March, 1918. List of permissible explosives, lamps, and motors tested prior to April 30, 1918, compiled by Albert H. Fay. 23 pages, 8vo. Technical Paper 144. The Quick Determination of Incombustible Matter in Coal and Rock-Dust Mixtures in Mines, by A. C. Fieldner, W. A. Selvig and F. D. Osgood. 36 pages, illustrations, plate, 8vo. Technical Paper 172, Effects of Moisture on the Spontaneous Heating of Stored Coal, by S. H. Katz and H. C. Porter. 25 pages, illustrations, plate, 8vo. Technical Paper 185, Use of the Interferometer in Gas Analysis, by Frank M. Seibert and Walter C. Harpster. 18 pages, illustrations, 8vo. Technical Paper 194, Report of the Committee on the Standardization of Mining Statistics, compiled by Albert H. Fay. 39 pages, 8vo. Chart of Properties of

Mine Gases, compiled by G. A. Burrell, 26 by 36 inches. Washington, Government Printing Office, 1917–18.

U. S. Department of Agriculture: Prevent Grain Dust Explosions and Fires. 7 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

U. S. Tariff Commission: Outline of its Work and Plans, 13 pages, 8vo. Tariff Information Series No. 3. Silk and Manufactures of Silk, Schedule L. 163 pages, 8vo. Washington, Government Printing Office 1917–18.

School of Mines and Metallurgy: University of Missouri Bulletin, March 1918. Catalogue 1917–18. 169 pages, illustrations, 8vo. Rolla, Mo., 1918

A Modern Plant for Thawing Coal Cars. S. W. LINN. (*The Railway Age,* vol. 64, No. 13, p. 805, March 29, 1918).—Scarcity of labor and prolonged severely cold weather have much to do with delays in moving materials from producer to consumer, and very little can be done on short notice to offset the retarding effect of either of these conditions. In winter the freezing of materials, like coal, ore, sand, or gravel, which are usually shipped in open-top cars, adds greatly to the cost and delay of their delivery. When these commodities are shipped any considerable distance and are held on cars for several days, they are in a more or less frozen condition, depending on the severity of the weather and the amount of moisture in them.

At tidewater coal shipping ports the handling of frozen coal forms one of the most serious problems in winter operation. It is necessary at most of these ports where coal is unloaded from cars to boats by car dumper that the work be carried on in winter weather at the same rate as in summer. Much of the coast towns' supply of coal depends on shipment from these ports. Various methods for thawing coal in the cars have been used, most of them without great success from an economical operating standpoint. The plan mostly used until about seven years ago was the so-called point system. Thawing was attempted by driving gas pipes into the frozen coal and introducing steam into the coal through these pipes. This was an expensive and awkward method, and was attended by considerable danger to workmen as open to the objection that the coal was left in a saturated condition.

The thawing plants operated by the Eastern Coal Dock Company at its coal-unloading plants at Philadelphia and South Amboy, N. J., the latest of which consists of a concrete building, 570 feet long, with three rooms, each containing one track. Heated air is employed for thawing. The air is carried the full length of the building through ducts and discharged through flues arranged to discharge upwardly toward the bottom of the cars. This plant has a holding capacity of 42 cars, each 40 feet long. Under severe freezing conditions and with the average coal, from one and a half to two hours are required to thaw the coal so that it will unload freely.

CURRENT TOPICS

The Control of Industrial and Scientific Information. W. RINTOUL. (*Journal of the Society of Chemical Industry*, vol. 37, No. 4, p. 67R, February 28, 1918).—Among the essentials necessary to success in industrial organization, the collection of information bearing on the industry in question and filing it in available form are of paramount importance. The most difficult duty which falls to the lot of the department devoted to the collection of data is the grading of the information secured into that which is of sufficient importance for record and that which is likely to be of ephemeral interest only. Another difficulty to be faced is the selection of the most readily appreciable method of filing the collected information. Perhaps the best solution of this difficulty is the adoption, as the main guide of filing, of the mechanical form in which the information is presented; that is to say, whether as a book, a periodical, an extract, or patent, a typewritten document, or a manuscript, without any reference whatever to the subject to which the information in question relates. This method of filing posseses the great advantage of compactness, and in most cases the economical use of space available is an important consideration.

Having fixed upon a method of filing, a reliable index becomes a necessity. It is a common impression that no great degree of skill or experience is necessary for the construction of a satisfactory index, but the idea is entirely fallacious. On one occasion some five individuals, all of whom were experts in one or another division of knowledge, but with no great experience in indexing, attempted to construct such an index. After some months of work it was found that so many contradictory decisions had been made that much confusion had already been introduced, and it was realized that in a very few years' time the index would become so complicated as to be unworkable. It was therefore decided to study more carefully the various systems that have been proposed from time to time, with the object of selecting the one best adapted to meet existing conditions. The choice finally lay between that adopted in 1905 by the "Institut International de Bibliographie" of Brussels and that proposed by J. Kaiser in his monograph on "Systematic Indexing," published in 1911. This is a card system in which concrete terms are used as the main guides, followed by sub-guides relating to geographical position and process. The card contains an epitome of the information to be found in the original, followed by a reference which enables the original article to be consulted. The experience gained in constructing and using an index of 150,000 cards during the past five years has led to the opinion that it admirably fulfils the object for which it was designated.

Vitamines. W. RAMSDEN. (*Journal of the Society of Chemical Industry*, vol. 37, No. 4, p. 53T, February 28, 1918).—It has been discovered during the last twenty years that as wide a variety of animals as pigeons, fowls, rats, pigs, and man, if fed exclusively on polished rice, develop the disease known as beri-beri, characterized by serious changes in the peripheral nerves, and that a water or a 90 per cent. alcohol extract of the rice-polishings contains a substance of which very minute quantities prevent or cure the disease. By careful and laborious experiments with rice and other diets it has been shown that this substance is widely spread in the common foodstuffs and that its presence is essential for life. Attempts to isolate it in a pure state in sufficient quantity for chemical investigation have not hitherto been completely successful, but enough has been ascertained to make certain that it is neither a protein, fat, nor carbohydrate, nor inded any of the known constituents of plants or animals. Funk has proposed for it the name "the anti-beri-beri vitamine," and this term "vitamine," although open to many objections, has been widely adopted for substances of this type. The name "sitacoid," meaning a medicine-like substance associated with food, is suggested by the writer as accurately descriptive and not implying a knowledge of their chemical character which we do not possess.

Most foodstuffs contain adequate amounts of the anti-beri-beri substance, but it is important to note that white flour, polished rice, and arrow-root, and probably also "corn-flour," and much of what is sold as tapioca, and semolina contain none. Ordinary white bread probably contains a little derived from its yeast, but certainly not enough for health unless supplemented by other foodstuffs. Wheat-bran contains a little, wheat embryo a considerable quantity. It is present in quantity in yolk of egg, cod-liver oil, and all animal fats investigated (with the remarkable exception of lard), milk, cheese, butter, margarine made from animal fats, green leaves, soya beans, millet, and flaxseed. It is absent from lard and all vegetable oils (almond, maize, cottonseed, sunflower seed, linseed, and soya bean oils) and margarines made from them. It is present, although apparently in small amount only, in the (entire) seed of wheat, oats, maize, rye, and cotton seed.

Methods of Rapid Nickel Plating. ANON. (*The Metal Record and Electroplater*, vol. 4, No. 3, p. 85, March, 1918.)—Nickel plating has been practised for about fifty years, and in all that time, up to the last two or three years, platers have been satisfied with the slow process of electrodeposition of nickel as practised by their fathers before them. That is, they have been content to deposit nickel with the low rate of 3 to 5 ampères per square foot. A few years ago "rapid nickel salts," claimed to permit of nickelling at two or three times the usual rate, were imported from Europe. These proved to be only mixtures capable of yielding more concentrated solutions

than that enemy of progress, the double sulphate, which for so long has masqueraded as the plater's friend. The American plater ultimately learned to make up his own rapid solution, and as a result nickelling at 10 to 20 ampères per square foot is very common to-day.

The most recent step in rapid plating is the remarkable work of Kalmus and Barrows in plating with cobalt at 150 ampères per square foot, turning out commercial plating of high grade in three minutes. This achievement with cobalt suggested the desirability of obtaining similar effects with the cheaper nickel solution. In so far as the excellent results of the cobalt solution depend upon its extreme concentration (312 grammes of anhydrous cobalt sulphate per litre), it should be possible to duplicate them with nickel, since its salts are equally soluble. It is, however, in anode corrosion and in its absorption of hydrogen that nickel is inferor to cobalt as a metal for electroplating. The nickel anode becomes "passive" on the slightest provocation, and, instead of all the current dissolving nickel as is desired, a portion of it is spent in producing acid at the anode. Besides cutting down the efficiency of deposition, this acid causes hydrogen to be evolved in considerable quantity on the cathode, where some of it is absorbed by the deposit. Absorption of hydrogen by nickel renders it hard and brittle, and is likely to cause it to curl away from the metal on which it is deposited.

The addition of a small amount of some chloride to the sulphate solution generally employed for nickel plating is a well-known remedy for this passivity of the anode. Previous experience with hot nickel solutions indicates their use for overcoming these difficulties, since in a hot solution anode corrosion is greatly improved and absorption of hydrogen is lessened. A 25-gallon hot nickel bath was used at 125 to 150 ampères per square foot with great satisfaction, producing in five minutes a heavier deposit than is obtained in an hour with the usual rapid bath at 10 ampères per square foot. This solution contains nickel sulphate (single salt), nickel chloride, and boric acid. In spite of the extreme current density, the deposits were superior in quality and adherence to ordinary nickel plate.

PRESS OF
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PHILADELPHIA

THE FRANKLIN INSTITUTE

ANNOUNCEMENTS

MEETINGS

COMMITTEE ON SCIENCE AND THE ARTS. First Wednesday of each month, 8 P.M. (except July and August).

BOARD OF MANAGERS. Second Wednesday of each month, 3.30 P.M.

INSTITUTE. Third Wednesday of each month (except June, July, August and September), 8 P.M.

SECTION MEETINGS. Thursday Evenings (except week of Institute Meeting), 8 o'clock. October 1 to April 30.

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CHANGES OF ADDRESS

Members are particularly requested to inform the Secretary of changes of address.

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For further information and membership application blanks address the SECRETARY of THE INSTITUTE.

THE FRANKLIN INSTITUTE AWARDS

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM

THE City of Philadelphia holds in trust under the legacy of John Scott, of Edinburgh, a sum of money the interest of which is to be used for the encouragement of "ingenious men and women who make useful inventions." **The legacy provides for the distribution of a Medal, inscribed "To the Most Deserving," and Money Premium in the sum of $20 to such persons whose inventions shall merit the same.** The examination of the inventions submitted for the Medal and Premium has been delegated by the Board of Directors of City Trusts, of the City of Philadelphia, to THE FRANKLIN INSTITUTE, and THE INSTITUTE, under the competent assistance of its Committee on Science and the Arts, undertakes to make investigations free of charge and to recommend for the award all meritorious inventions.

Applications should be addressed to the Secretary of THE FRANKLIN INSTITUTE, from whom all information relative thereto may be obtained.

Pursuant to the regulations for the award of the John Scott Legacy Medal and Premium, THE FRANKLIN INSTITUTE, of the State of Pennsylvania, has under consideration favorable reports upon the applications advertised in this JOURNAL. Any objection to the proposed awards, based on evidence of lack of originality or merit of the invention, should be communicated to the Secretary of THE INSTITUTE within three months of the date of notice.

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The Elliott Cresson Medal (Gold Medal and Diploma).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal and Diploma).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles; and for papers of especial merit that have been presented to the Institute and published in its JOURNAL.

The Edward Longstreth Medal of Merit (Silver Medal and Diploma).—This medal, with a money premium when the accumulated interest of the fund permits, is awarded for meritorious work in science or the arts; including papers relating to such subjects originally read before the Institute, and papers presented to the Institute and published in its JOURNAL. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance, or for meritorious papers presented to the Institute and published in its JOURNAL.

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The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with THE FRANKLIN INSTITUTE the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not transmitted with the same velocity."

For further information relating to these awards apply to the Secretary of the Institute.

THE FRANKLIN INSTITUTE AWARDS

Notice is hereby given that the Committee on Science and the Arts of THE FRANKLIN INSTITUTE has recommended the award of

The Elliott Cresson Medal

JOINTLY TO

Reynold Janney

New York, N. Y.

and

Harvey D. Williams

Wallingford, Conn.

FOR THE INVENTION OF THE

WATERBURY HYDRAULIC SPEED GEAR

Any objection to the above recommendation based on evidence of lack of merit should be communicated within three months of the date of this notice to the Secretary of THE FRANKLIN INSTITUTE, Philadelphia.

GEO. A. HOADLEY,
Acting Secretary.

HALL OF THE INSTITUTE
July, 1918.